THE PSYCHOLOGY OF EFFICIENCY

AN EXPERIMENTAL STUDY OF THE PROCESSES INVOLVED IN THE SOLUTION OF MECHANICAL PUZZLES AND IN THE ACQUISITION OF SKILL IN THEIR MANIPULATION

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CHAPTER I

INTRODUCTION

1. STATEMENT OF PROBLEM

THE present study is an attempt, under simplified conditions and with special emphasis upon the motor type of process, to analyze human methods of meeting relatively novel situations and of reducing their control to acts of skill. It thus involves the taking of practise curves, and is similar to the studies previously made by other investigators in learning processes such as the acquisition of telegraphy[1] or of shorthand,[2] of a foreign language,[3] of skill in typewriting[4] and in tossing balls,[5] etc. It differs from these studies, however, in that the original situation is distinctly of the problem type, and in that the acquisition of skill in the succeeding manipulations also involves the problem type of consciousness to a very considerable degree.

On account of this emphasis on the factor of thought, the study is also related to the recent investigations on the thought processes carried on chiefly in Germany.[6] The interest in the present study,

[1] Bryan and Harter, *Psychological Review*, Vol. IV., p. 27; Vol. VI., pp. 346–375.

[2] E. F. Swift, *American Journal of Psychology*, Vol. XIV., pp. 224–230.

[3] E. F. Swift, "Garman Memorial Volume of Studies in Philosophy and Psychology," pp. 297–313.

[4] E. F. Swift, *Psychological Bulletin*, Vol. I., p. 295. W. F. Book, "The Psychology of Skill," *University of Montana Publications in Psychology*, Psychological Series No. 1.

[5] E. F. Swift, *American Journal of Psychology*, Vol XIV., pp. 201–224.

[6] K. Marbe, "Experimentell-psychologische Untersuchungen über das Urteil, eine Einleitung in die Logik," 1901. A. Binet, "L'étude experimentale de l'intelligence," 1903. H. J. Watt, "Experimentelle Beiträge zu einer Theorie des Denkens," *Arch. f. d. ges. Psych.*, iv., 1905. N. Ach, "Ueber die Willensthätigkeit und das Denken," 1905. A. Messer, "Experimentell psychologische Untersuchungen über das Denken," *Arch. f. d. ges. Psych.*, viii, 1906. K. Bühler, "Tatsachen und Probleme zu einer Psychologie der Denkvorgänge," *Arch. f. d. ges. Psych.*, ix., 1907. G. Störring, "Experimentelle Untersuchungen über

however, is dynamic rather than structural. It deals with the part which different sorts of thought processes actually play in the meeting of novel situations, and, as far as possible, with the conditions favoring the development of variations. From the latter point of view there are points of contact with Royce's study of invention.[1]

The problem as thus treated may have lost somewhat in precision on account of the breadth of processes entailed, but it is hoped that there has been a corresponding gain in continuity and in the exhibition of organic relationships. The writer plans to follow up this rather general study with detailed investigations on some of the special problems raised.

The study is of human methods, but it was undertaken with the hope that some light might be thrown on animal methods of learning as well. The studies were not planned to have exact similarity in material to that used with animals, but there are, nevertheless, certain fundamental points in common, such as the situations being novel and demanding some form of manipulation.

2. Material Employed

a. General Description.—Mechanical puzzles were chosen as the material to be employed. The term mechanical is used to indicate that all the puzzles involved actual manipulation of materials. No trick puzzles were used, *i. e.*, all the puzzles were possible of solution and all the physical materials required were supplied to the subject. The puzzles might be roughly classified into analytical and synthetical, and, again, into tridimensional and bidimensional. Most of the puzzles were analytical and tridimensional. These were for the most part made of wire, and involved the removing of some part of the apparatus, such as a ring, star or heart, from the rest. Some of the puzzles were of the synthetic or construction type, such as the familiar jig-saw puzzles or rarer forms involving three dimensions.

The movements required for solution were, in general, rather complex. In certain cases the degree of complexity could be indefinitely increased, and yet a single rule be developed for solution in the various resulting forms.

b. Advantages.—The puzzles presented the following advantages in relation to the purpose of the experiment:

(1) They constituted genuine problems. None of the subjects solved an unfamiliar one at sight.

einfache Schlussprozesse," *Arch. f. d. ges. Psych.*, xi., 1908. R. S. Woodworth, *Journal of Philosophy, etc.*, 1907, 4, 170. E. B. Titchener, "Lectures on the Experimental Psychology of the Thought Processes," 1909.

[1] J. Royce, *Psychological Review*, Vol. V., pp. 113–144.

(2) They involved transformations in three dimensions, and the ability to construct transformations in the third dimension seems to be a decidedly undeveloped function. For this reason the problems were in a special sense "novel."

(3) The form of the puzzles invited immediate motor response, and yet highly indirect types of solution were in some cases necessary. The result was a wide range of methods varying from "accident" to anticipatory analysis of a most complex sort.

(4) The puzzles fell into several distinct groups according to the principle of solution. Each group was composed of several puzzles differing from each other more or less widely in detail. Opportunity was thus furnished for the study of the place of "perception of similarity" in "transfer."

(5) The physical manipulation of the puzzles was easy, and a long series could be taken at a single sitting without perceptible fatigue.

(6) The movements of the subject could be recorded by the experimenter and this objective account of his behavior could then be compared with his own account given during or at the close of the trial.

(7) Puzzle material can readily be employed with children, with primitive people, and possibly with the mentally abnormal, and it has many points of similarity with the "puzzle-boxes" used with animals. It thus offers rather unusual advantages for comparative psychology.

3. Conduct of the Experiments

a. General Procedure.—The method of conducting the experiments was very simple. The subject was seated comfortably at a table, on which the puzzle was placed. The puzzle was covered by a screen. After the warning signal a starting signal was given, and the screen removed. When the manipulation for the given trial had been completed, the puzzle was immediately removed by the operator and prepared for the following trial. The subject was given no opportunity to examine the puzzle except during the actual trial.

The number of trials for a given subject with a given puzzle varied from 1 to 1,440. The standard number was 50. Fifty-one series were taken in which the number of trials composing the series equaled or exceeded 50.

The number of trials at a given sitting varied with the subject and the puzzle. The sittings were usually of an hour and a half in length. In some cases an entire series of 50 trials was completed in this interval. In others several periods were consumed in gaining

the first solution. When more than a single sitting was required for a given series, that fact is noted in the tables or the accompanying discussion.

The times given, unless otherwise specified, are for one-way solutions, *i. e.*, the subjects took the puzzles apart, but the operator put them together again out of view of the subjects. The exceptions referred to were all the puzzles solved by *Rr* and some of those solved by *Wh*. In these cases, the subject took the puzzle apart and also put it together again. The time was taken separately for each operation, two practise curves being thus kept for each puzzle.

Only one subject was used at a time.

b. Instructions to Subjects.—Only the most general indications as to the nature of the solutions required were given the subjects. Thus, in the case of the "analytical" puzzles, the subjects were simply told, "Some part of the puzzle is to be removed." What that was they were to determine on examining the puzzle. The indefiniteness of the instructions made the problem more difficult, but it was the means of testing such qualities as the ability to size up a situation, to eliminate the irrelevant, and to use independent judgment in that selection. It also brought out into prominence and made available for study the great rôle played by more or less explicitly conscious assumptions as to the nature of the problem. All of these things it was the purpose of the study to investigate. Since all knew the nature of the problem in detail by the second trial, the later course of the practise curve was not affected.

The subjects were instructed to "solve" the puzzle each time as rapidly as they could consistently with the stage of progress attained. They worked with knowledge of results as far as the time taken by the separate trials was concerned. No information was given them concerning errors made. The guiding principle was to keep the subjects stimulated to the most efficient activity. Their interest during the first few trials of a given series was naturally mainly on working out the essential elements of the problem. After that had been accomplished, their attention was more and more given to the development of speed. With the exception of a very few cases, carefully noted, the subjects did not stop to repeat a part process during a given trial. The analyses performed, whether of the main or the minor elements of manipulation, were thus of a snap-shot order. Had the plan of allowing the part processes to be repeated been followed, the drops in the curves would undoubtedly have been steeper, but it would have been more difficult to evaluate the results, especially in comparison with other practise curves.

c. Records.—The subject's account was written or dictated by

him at the close of each trial. In the earlier solutions in a given series, *i. e.*, in the first two or three trials with a new puzzle, in the case of a number of the subjects, a running account was kept during the process of solution. This comprised exclamations showing the emotional attitude, and more or less extensive descriptions by the subjects of what they were doing and why they were doing it. These remarks were recorded by the experimenter.

The experimenter's account consisted of a description of the movements made by the subject, and, as just stated, of whatever he may have said during the trial. Abbreviations for the important movements were employed, and the movements were recorded at the time of their occurrence. The fact that the movements were in three dimensions, and were variable and complex, made it seem unwise to attempt a mechanical form of registration.

The discussion in the later sections is, in general, based on this triple account: the experimenter's description of what was done, the subject's account written at the close of each trial, and the remarks made by the subject during the trial.

d. Chronometer.—The times of the separate trials were taken by means of a split-second cumulative stop-watch reading to tenths of a second. The split hand proved of value in taking times for the part processes as well as of the whole. The times taken during the first trial varied from a maximum of 33,060 seconds, nearly ten hours, to 7 seconds. The times of the shortest trials varied from 0.4 second (highly specialized conditions for one subject in only one puzzle) to 824 8 seconds. Only in the one special case just mentioned did the time fall below one second. The time fell below two seconds only in 5 puzzles out of 36, 80 per cent. of these cases being in two puzzles. The percentages of the total number of cases in which the times fell below one and two seconds respectively are as follows: below one second, one fifth of 1 per cent.; below two seconds, 2 per cent. The percentages are based on a total of 7,000 cases. It is believed, then, that the chronometer was sufficiently refined for the purpose in hand, especially since the low times are restricted to special cases and the conclusions do not rest on a high degree of accuracy in those cases.

4. Individuals Serving as Subjects

All except five of the subjects had done work in psychology and had some special interest in it. The five mentioned as exceptions were four boys from sixteen to twenty years of age employed about the campus, and the laboratory mechanician. Of the other subjects seven were engaged in instruction in psychology or in research.

Two were instructors in related fields and had had considerable psychological training. The remainder were graduate or special students in psychology. Five of the subjects were women.

The designations for the different subjects is as follows:

The four boys—with grammar school or high school training —*Co, St, Mc, Ry.*

The mechanician, *We.*

The seven with professional training in psychology, *Wh, Bg, Rr, Kk, Re, Hn, Bs.*

The two instructors in related fields, *Br, Ft.*

The graduate and special students, *Rd, Ta, Tz, Fe, Mt, Hy, Rg, Pz, Be, Rs, Ds, Pn, Tr.*

There were, altogether, twenty-seven subjects. Nine of them completed long series on at least six puzzles each. The remainder were given fewer puzzles or shorter series. The nine subjects who took the long series with six or more puzzles were *Co, St, Mc, Wh, Bg, Rr, Rd, Ta, Tz;* the first three in each of groups 1, 3, and 5 given above. The five women subjects were *Rd, Fe, Hy, Rg,* and *Ds.*

5. Explanation of Terms

The terms "analysis," "variation," and "transfer" are used very freely in the discussion which follows.

The term "analysis" is used very broadly for the whole process of mental emphasis, the setting up of an hypothesis on the basis of this emphasis, and the various ways of testing the hypothesis. It would include, at one extreme, the case where the entire process is in terms of ideas, where the thinking is highly symbolic and complex, and where the testing is also done by further thinking, and, at the other extreme, the case where there is a simple noticing of a variation taking place unpremeditatedly and its purposive completion or later adoption.

The term "variation" was used in the statement just given concerning the term "analysis." It is used for the whole set of conscious or "unconscious" changes in methods of attack which might in any way be considered novel. A process of "analysis" would be a "variation," but there might be variations which would not be analyzed.

The term "transfer" is used in the sense involved in the recent discussions of general and special training.

6. Acknowledgments

The writer first became interested in the problems of behavior through an experimental study on the behavior of animals made

under the direction of Professor Edward L. Thorndike. The present investigation of human methods of behavior under conditions analogous to those employed with animals is a direct outgrowth from the study mentioned.

The use of puzzles as material was suggested by Professor E. H. Lindley's "Study of Puzzles."*

The especial interest in the problem type of situation was due to Professor John Dewey and to Professor George H. Meade.

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*E. H. Lindley, "A Study of Puzzles," *American Journal of Psychology*, Vol. VIII., pp. 431 ff.

CHAPTER II

General Statement of Results

1. Methods of Learning

a. "Human" and "Animal."—A great deal has been made of the contrast between "human" and "animal" methods of learning. The latter has been represented as a process of mechanical stamping in of those random or instinctively determined movements which have brought success, and the stamping out of those which have failed.[1] The "human" method has been described as one of understanding of principles and the consequent learning by a single successful experience.[2] These designations, human and animal, have been used as equivalents of "trial and success" and "reasoning" respectively, and so have stood primarily for opposed types of learning wherever found, and secondarily to mark characteristic differences between the learning of men and of animals. The method of "trial and success" has been said to take place under conditions of attention in the case of animals and to be found in men in the acquisition of skill where the attention was on the result rather than on the process or where the variations occurred and built themselves up into habits unconsciously.[3] The results of the present study go to show:

(1) That even where the task is not mainly that of gaining a new *form of motor control but is essentially that of "learning by understanding"* there are important differences in human methods of learning;

(2) That some of these methods show objective points of similarity to animal methods;

(3) That the "human" and "animal" methods should not be considered as exhaustive of the forms of learning, but as two out of a larger and, at present, undetermined number;

(4) That the "human" and "animal" methods should be considered as limiting members of a series of methods in which different types of analysis play an important if not the determining rôle;

[1] E. L. Thorndike, "Animal Intelligence," p. 45.
[2] M. F. Washburn, "The Animal Mind," p. 237.
[3] E. L. Thorndike, "Animal Intelligence," pp. 101-2.

This lack of ideas closely related to the puzzles and of development of the fundamental capacity of constructing transformations in three dimensions was reflected in the attitude of the subjects. A number spoke, especially in dealing with their first puzzle, of feeling helpless or hopeless and of being convinced that the thing to be done was impossible.

Highly complex reasoning processes, sudden drops in the curves to a permanently low level, quick adoption of shortcuts, and elimination of erroneous or uneconomical forms of manipulation were, of course, also found, but the opposites of these, as stated above, were surprisingly in evidence.

b. Types of Analysis.—As stated in the introduction, the term "analysis" is used very broadly for the whole process of mental emphasis, whether of the analytic or synthetic type in the narrower sense of the terms. The getting of a single organized view of a mass of details would thus be classed as "analysis," not as synthesis.

It was suggested above that instead of simply contrasting two methods of learning, the "human" and the "animal," it might be more profitable to consider these as limiting cases in a series of grades or kinds of analysis, and to attempt, as far as possible, to chart out these various types. It might very well follow, were such a complete examination of human methods and their conscious accompaniments made, that the various and, probably, fairly numerous forms of learning employed by animals might be more clearly distinguished and evaluated. The results of this study can go only a little way in this direction, and the distinctions given below are not presented as in any way exhaustive or exclusive, but as indicating the sorts of differences which appeared most prominently in the course of the experiments.

The analyses met with in the experiments are classified from the following points of view: (1) Explicitness and results, (2) extent, (3) time-relations to motor variations, (4) material.

(1) *Explicitness and Results.*—These are classified together because the latter may usually be taken as a measure of the former. There is a wide range of variation in felt clearness from the extremely vague to the perfectly clear. This range of felt clearness is matched by difference in results. Some of these differences stated in terms of clearness or results or both are as follows: (*a*) Vague feeling of familiarity when the variation chances to occur again, (*b*) explicit recognition of the variation when it recurs, accompanied by anticipation of it on experience of its immediate antecedent, (*c*) ability to image it factually in part, (*d*) ability to image it completely, (*e*) ability to describe it verbally, (*f*) ability to use it in

novel combinations and to state a general formula for its use under varying conditions.

As exceptions to this parallelism of felt clearness and results may be mentioned the feeling of perfect clearness which sometimes occurs but is not followed by ability to recall, and the many instances of illusions, where solutions that look perfectly clear for the moment are later seen to be impossible.

In the list given just above of grades of explicitness or clearness there was no intention of dealing with the different degrees of reality-feeling or belief which might also to a certain extent parallel that series.

(2) *Extent.*—The basis of division here is the extent to which the entire manipulation of a given puzzle is analyzed. The subdivisions, rather arbitrarily chosen, are (*a*) partial, (*b*) schematic, (*c*) total. In discussing these separate subdivisions other criteria will, to a certain extent, be introduced.

(*a*) Partial. One of the most significant forms of partial analysis met with was the picking out of the portion of the puzzle to be attacked. In many cases this was a mere spatial analysis, "locus" analysis, without involving any perception of mechanical necessities. Possibly the solution came once by accident and the subject noticed the part of the puzzle concerned. Such "locus" analysis is followed by an abrupt drop in the curve owing to the immediate elimination of random movements connected with other parts of the figure. There is no gradual wearing away or "stamping out" but a sudden and complete elimination, and this with a very low grade of analysis. The sudden drops in many of the animal curves may well be due to this sort of analysis. Random movements still occur, but they are limited to the "locus."

Another important form of partial analysis noticed was that of a single step in the process while the other steps were attained only by random movement. This single step was often the final one. The solution would come accidentally, but the subject would notice the last step. In the subsequent trials he would know what to do if he chanced to get to that step but not how to get there.

(*b*) Schematic. In some cases the subject would glimpse the main line of attack, the general plan of solution, but without having analyzed the steps in detail.

(*c*) Total. This covers the cases where the analysis reaches all the steps or elementary movements. The cases included may be subdivided according to the degree of unity obtained in the organization of these elements.

In some cases the whole process remains merely a series of different steps arbitrarily following each other.

sensory and image referring to the lower, and perceptual and ideational to the upper limits of mental organization in the respective fields. Both divisions might be cross-classified again into factual and verbal.

It has been customary to contrast perceptual with ideational analyses to the discredit of the former, and to make the presence or absence of images the important question in the estimation of animal intelligence. To the writer it seems probable that there are wide differences in value in the sorts of analysis to be found within the perceptual field itself, and that these differences may rank in importance with the difference between the fields as perceptual or ideational, peripheral or central. These differences have, to a certain extent, been included in the preceding classifications. Thus, a "locus" analysis and an analysis of mechanical relations might both be within the perceptual field and yet differ widely in value. The process of perceptual analysis does not seem to consist in plastering an image on to a percept, but it seems to be a direct transformation within the perceptual field itself. The experience seems to correspond to what some writers have spoken of as a "movement of attention." The experience of the analysis is distinct from that of ordinary perception, on the one hand, and from that of a motor impulse on the other. It is oftentimes a striking experience and seems to come with a rush or as a flash. These suggestions are based directly on the writer's introspections, but are supported by occasional remarks of subjects to the effect that they seemed to see the relations involved in solution directly, and without the use of imagery.

The advantage of the ideational field over the perceptual, in part at least, was noted as consisting in the lopping off of irrelevant details, the reduction of distracting motor tendencies, which are quite pronounced with the perceptual field, and the resulting ability in the case of the ideational image field of keeping the entire system of transformations within the span of consciousness. Part of the advantage of the verbal image field over the factual is to be found in the still further foreshortening made possible and also in the greater control in the way of recall. The verbal image does not always come after the factual but is used in building up the factual, the latter often being dragged in bit by bit and held by means of words until a total factual image has been built up. The complete factual image may then be superseded by a compact verbal statement. The generalized formula was essential in the case of some of the puzzles in which complex changes could be introduced, the changes, however, being in accordance with a single principle.

There was no magic in the verbal statement, however, as was shown by failure in a case where the rule was memorized without the performance of the analyses of which it was the expression. The generalized formula was most readily developed by those who had been trained in the logic of scientific method.

The relative independence of analysis and imagery is shown by the double fact that, on the one hand, the mere presence of images directly related to the solution of the problem in hand was found to be of no avail unless the act of analysis were performed, and, on the other hand, that previous experience seemed to be effective in determining a perceptual analysis in which no trace of imagery could be found.

The general point which it has been the aim of this section to maintain is that in place of merely contrasting extreme types of learning, such as the "human" and the "animal," or of making a hierarchy of percepts, images and concepts, what is needed is a working out of the sorts of analysis which may occur within the perceptual field, and within the image field, whether factual or verbal, and, in connection with this, to determine more precisely the significance of the mental stuff, or fields, themselves. On this double basis it might be possible to exhibit the rich complexity of human forms of learning, and by means of this to catalogue the narrower but still surprisingly extensive range of animal methods. The gross characterizations would still have their value, but the finer distinctions would undoubtedly prove significant in precise evaluations.

2. Conditions of Efficiency

a. The Fact of Variations.—It seems to be pretty generally agreed that abrupt drops in time, in a given practise series, or sharp increases in score when the times are kept constant, are due to variations in method. In accordance with this plateaus have been interpreted as conditions of stagnation in which variations fail to appear.[4] In the puzzle experiments this general result was confirmed. The efficiency was found to be directly dependent upon success in getting the most appropriate methods or technique.

b. The Consciousness of Variations.—It has been maintained by some that variations in method are most effective when they are not attended to, when they come and also build themselves into habits "unconsciously" or "marginally" rather than "consciously" or "focally."[5] The results of the puzzle experiments are in accord with

[4] Book, "The Psychology of Skill," p. 158.

[5] Swift, "Mind in the Making," p. 213. Book, "The Psychology of Skill," p. 171.

was what might be called the personal attitude of the subject. Two forms of personal attitude inimical to the occurrence or utilization of variations appeared with especial prominence. They might be called the submissive, or suggestible, and the self-attentive.

The former of these appears in the presence of a person supposed to "know the answer." The object of attention is here the person with the "prestige-suggestion" rather than the problem itself. Not only is the tendency for variations to appear around the problem inhibited by the shift of attention to the "prestige-person," but the special forms of variation which constitute criticism and evaluation are similarly affected. This attitude must be carefully reckoned with in all tests of intelligence. In the puzzle experiments this tendency was so marked with two of the subjects that it was necessary for the operator to entirely screen himself from view in order that slight movements of his should not be taken, correctly or erroneously, as indications of the correctness or incorrectness of certain manipulations. This negative effect of the "prestige-suggestion" was even more marked in certain cases of reactions to novel situations of a more distinctly social type than the puzzle experiments.

In the "self-attentive" attitude the attention, as is suggested by the name, is not on the problem but on the self. The self is felt to be on trial. "What sort of a self shall I and others consider myself to be?" is the question which occupies attention, and this is usually accompanied by a state of worry, of emotional tension, which still further distracts from the problem in hand.

These two attitudes are closely related in that both arise from a lack of confidence in the self, a lack of a self-confidence which would permit the attention to go to the problem in hand. They are especially likely to arise in face of a novel situation, one concerning which the subject thinks himself to be ignorant or inept. The puzzles presented a novel situation in this sense, and the occurrence of these attitudes was especially prominent in the first attempts of a subject with his first puzzle. In some cases the first success brought a complete reversal of attitude in dealing with later puzzles even in cases where there were few elements in common between the puzzles concerned.

(3) Assumptions. The variability of the subjects was affected not merely by their physical condition and emotional attitude, but also by the general assumptions which they made and more or less explicitly held in mind concerning the nature of the special problem in hand. These assumptions often, apparently, were set up accidentally and became thoroughly entrenched without being subjected to criticism. The first glance at a puzzle seemed in many cases to

suggest a particular way of stating the problem or of defining the place or type of solution without there being any active search for other ways of looking at the matter or any criticism of the way accepted. The assumption thus uncritically set up in some cases limited the movements made by the subject to a certain portion of the puzzle, and consequently, in some instances, rendered the solution impossible.

This negating effect of a given assumption was qualitative as well as spatial. The essential parts of the apparatus might be selected but with the wrong assumption. This assumption, then, either limited the motor variations or made the subject insensitive to variations not in line with the assumption in question. In some cases the appropriate variation would take place many times but would pass unnoticed. To the observer it would seem that the subject must have a negative hallucination in regard to the variation in question.

The assumptions often had an inertia, an apparently volitional persistency about them, which seemed inversely proportional to the amount of critical consideration accorded to them.

These fixed assumptions were broken up in several ways. In some cases the puzzle was solved almost immediately on coming back to it later in the day. The particular set of consciousness had been broken up by this change and new points of view were possible. There were a number of rather striking cases of a similar sort on first awaking in the morning. There seemed introspectively to be here not merely an increase in general variability due to physical freshness, but also a shifting of values and probabilities, which led to new lines of attack. At other times the change of point of view was more purposive. Random manipulation was occasionally adopted by the subjects with the hope that either the solution might be reached accidentally or that some novel position of the puzzle might suggest an opening. More sophisticated attempts were at times made, especially by those who had had training in logic and scientific methods. In these cases the assumption would be analyzed out, criticized, and modified or set aside while an attempt was made to get other assumptions, and even to exhaust the possibilities in the way of assumptions and then to take up the problem of their relative evaluation. The bare logical contradictory proved its value in stimulating this search for a concrete other.

The purposive employment of this technique of explicit consciousness and definition of assumptions, of search for new points of view, of rapid but tentative evaluation of assumptions and the thorough testing of the one chosen as most probable, with accompany-

ing avoidance of mere repetition, seems to have been a very valuable means of furthering efficiency in the solution of the problem. It was, of course, limited in effectiveness by differences in variability native to the individual or due to age, physical condition, presence of related habits and ideas, attitude, and the thousand and one factors whose happy balance is essential to maximum efficiency.

The shifting of assumptions whether occurring by accident or purpose often resulted directly in the solution. There were several instances of this sudden success after the subject had spent three or four hours in working under a given assumption and had become hopeless of the outcome and thoroughly disgusted with himself. In some of these cases the shift of assumptions was due to instructions given by the operator to the subject to critically define the assumption under which he was working, to seek out other assumptions, and to test them either in turn or in accordance with their probability.

In connection with the attempt to change assumptions there appeared at times an interesting shift in the accompanying feelings of probability. In one case of this sort the subject reported three distinct stages: (1) Hypothesis "A" looked impossible and "B" perfectly convincing, (2) "A" and "B" appeared of the same degree of probability, (3) "A" appeared convincing and "B" impossible.

3. Transfer

The term, transfer, is used rather broadly to include both the specific and general effects of a given experience on succeeding experiences.

a. Specific Motor Habits.—(1) A given subject was tested with a puzzle thrown in chance positions. He was then trained to approximately the physiological limit in handling four special but important positions. He developed no general rule to include his treatment of these special positions. He was then retested with the puzzle in chance positions. Another subject was trained entirely with chance positions, in a series approximately half the length of the first subject's series. The second tests of the first subject showed no improvement over the initial results and were inferior to those of the second subject. This failure to profit by the highly specialized training seems to have been due to the lack of a generalized rule of procedure. As it was, each chance position was first reduced to one of the four special positions and then the solution was proceeded with instead of being performed directly.

(2) A certain puzzle was so arranged that it could be presented in various forms. The manipulations for these various forms could all be comprised under a single formula. This general formula

could be deduced from any one of these special forms. A number of subjects were tried with this puzzle. As soon as skill was acquired in dealing with one form of the puzzle it was changed to another form. The subjects who developed the general formula during the solution of the first form were able to use the specialized habits built up in the first form in the second. Those who formed merely the special habits without developing the principle attempted to carry over the habits without modification and were greatly embarrassed by the change.

(3) A subject was tested with a puzzle in a given form. Then all the motor habits necessary for the rapid solution of this form were built up by practise on the separate acts of manipulation involved. The elements were organically related in the successive forms of the practise series, so that the practise was not on the separate elements merely but on their connections. At the close of the practise series the subject was given the complete form, which was identical with that of the initial test. This form was not recognized as being related to the practise series, and the habits built up there were not brought into use.

In general, the value of specific habits under a change of conditions depended directly on the presence of a general idea which would serve for their control.

b. Concrete Imagery.—The mere presence of imagery, although vivid and of closely related puzzles, was no guarantee of its efficiency. Very often attention rested on some superficial point of similarity and progress toward solution seemed to be delayed instead of hastened. The value of the image as well as of the motor habit depended on the precision of the analysis.

c. Attitudes and Attention.—As has been previously stated, the first success often brought a complete change of attitude toward the puzzles. This transfer or extension of mood seemed at times to be almost reflexly accomplished, so direct did it appear. A change in the subject's idea of himself, from that of one incapable of solving such a problem to one capable of doing so, probably played a part in the change of mood. A similar but less decided change of mood was at times accomplished, in the absence of success, by the suggestion that the subject was doing as well as others. An attitude of self-confidence was at times self-induced through an idea of its value, and subjects were able by this means to avoid a state of confusion when in difficulty, to which state they had previously fallen victims.

No evidence was secured in favor of an automatic change in level of attention, but there were indications of its indirect control by means of ideals of what constituted an efficient state of attention.

d. Ideals of Method.—The great significance of ideals of method has perhaps been sufficiently emphasized. This significance was especially striking in proportion as the situation in question was distinctly novel. The idea of efficiency as a goal to be reached, the ideals of scientific method, and the ideal of an optimum personal attitude were among the most important of these.

4. Memory

The most striking point in regard to memory was its relation to continued analysis. Memory cues were promptly substituted for continued perception of relations. This meant, where successfully carried out, a great saving in time, but very often the attempt was premature. There were illusions of memory with resulting errors and perhaps failure after initial success, and there was memorizing of irrelevant features along with the significant ones. In some cases the conviction as to the correctness of an erroneous memory was so great as to prevent further analysis and to keep the subject indefinitely at a fruitless line of attack. It was easier to rely upon memory than to analyze the relations out afresh, and this may have contributed something to its volitional character. In general, the subjects succeeded best who held their memories flexibly as hypotheses subject to rejection or revision as the case might be.

5. Plateaus and Hierarchies

The term plateau is here used in a broad sense to include periods of little improvement whether of long or short duration. Plateaus in which the times were fluctuating but remained at a high level occurred where there was a shifting back and forth between rival methods, more or less consciously employed, or where some feature remained intractable to control. Plateaus of the uniform type occurred where a single method had become well established which was not the most efficient one for the situation.

As has been stated earlier, the drops in the curve depended very largely on variations in method and their conscious use as hypotheses. Where the puzzle involved repetitive elements combined in complex ways, a most valuable variation was the getting of some mental grasp of the processes as a unity. Various forms of unity have been discussed under section 1, Extent of Analysis. In general, ability to anticipate the succeeding steps was most important for the process of short-circuiting, and where this process was total in character, in the way of a unitary view, the development of higher units of action was most rapidly attained.

CHAPTER III

The Solution of Problems

1. General Nature of the Processes of Solution

a. Accident and Analysis.—The solutions of the major puzzle-problem, on the one hand, and of the minor problems of manipulation concerned with the acquisition of skill, on the other, were of the most varied types as far as the relation of analysis to success is concerned. In general, the solutions were not the result of mere straightaway thinking and the consequent formulation of a thoroughgoing plan of action, but were the outcome of an extremely complex interrelation of more or less random impulses and of ideas.

In a number of cases the solution came entirely by accident as far as the essential movement was concerned, but, even then, there was usually some awareness of the general position just before or just after the successful movement. Thus, in one case of a purely accidental success a vivid visual impression of the final position was obtained, and the solution later flashed upon the subject by means of an involuntary analysis of the resulting image. In most cases of accidental success, however, instead of a precise analysis there resulted at first merely a limitation of the problem center to the general region or kind of movement connected with the solution.

In a contrasted type of cases anticipatory analysis played the leading rôle of determining the main line of solution and accidental impulses were effective merely in the detailed processes.

(1) A number of illustrations of the different ways in which the successes were actually achieved will next be given. These are grouped into four grades or types distinguished according to the relative dominance and temporal priority of accident or of analysis.

(*a*) In the following cases there was no element of anticipation of the result connected with the successful movement:

"The final solution was a sheer accident. I was just starting to put the parts back in the original position in order to begin a new solution, when I thought I saw my way through."—*Bg* (Semicircle and Ring Puzzle).

"I have no idea in the world how I did it. I remember moving the loop of the heart around the end of the bar, and the two pieces suddenly came apart."—*Mt* (Heart and Bow Puzzle).

List of Puzzles: Key to Plate I

1, Fan Wire; 2, Bicycle; 3, Semicircle and Ring; 4, Heart and Bow; 5, Hook and Eye; 6, Two Face.

7, Maze Wire; 8, Sliding Triangles; 9, Hinged Loop; 10, Hinged Dart; 11, Star and Crescent; 12, Hinged Rectangle; 13, Cross and Ring.

14, Double Hinged Dart; 15, Triple Horseshoe; 16, Triple Ring; 17, Hinged Dumbbell.

18, Jujitsu; 19, Twisted Nails; 20, Twisted Wire; 21, Twisted Anchors.

22, Fighting Pig; 23, Fighting Pig; 24, Fighting Pig; 25, Chain and Ring.

26, Chinese Ring 10; 27, Mounted Wire Loop; 28, Chinese Ring; 29, Double Circle and Semicircle; 30, Chinese Ring 6.

31, Six-piece Cross Long; 32, Twelve-piece Cross; 33, Wizard Cross; 34, See Dar.

35, Katzenjammer; 36, Lone Star War; 37, Race War.

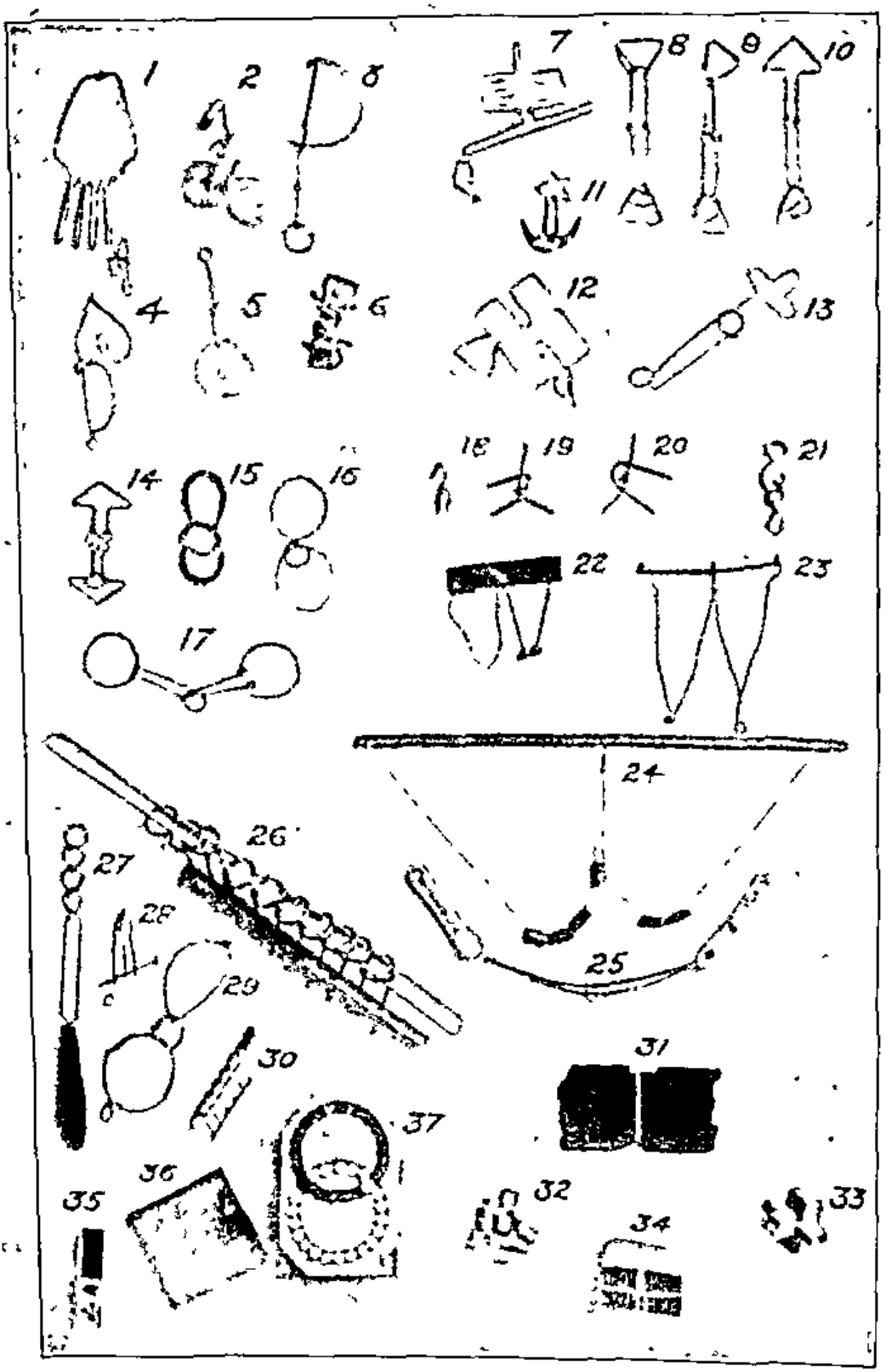
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PLATE I

"I tried random fumbling for several minutes purposely to see if anything would turn up. . . . I was only inattentively aware of what I was doing and did not plan it out. Was shocked with surprise when the rider came off."—*Rr* (Fan Wire Puzzle).

(*b*) In the cases to be given next the successful movement was entered upon accidentally, but was completed purposely and with more or less definite anticipation of the result.

" . . . So I shook the thing into the original position, and worked with it again aimlessly. The first thing I knew, the pointed ends were through the rings, and by working at this position in a manner hard to describe, I got the two apart."—*Wh* (Twisted Nails).

"I got it off in a way I had decided I couldn't. I saw a little way ahead that it would come off."—*Ta* (Wire Maze).

"The impulse to swing up the central loop came with a rush. It was followed by a partial perceptual cognition of its correctness."—*Rr* (Wire Maze).

"I tried this, at first idly, but then, as I progressed, I had a dim idea that I was doing something, and gave careful attention. As I did this, I saw that I had not merely made a difference, but had entirely freed the end of the chain which I had used as a loop, and that therefore I could entirely free the chain from the stick. I saw this a little before I came to it, but not when I started the movement of the loop through the hole, nor even when I passed the rest of the thing through the loop."—*Wh* (Chain and Ring).

"It seemed convenient to *keep* hold of the ring after I had once started it."—*Be* (Hinged Rectangle).

(*c*) In the following group the general locus of the essential movement or some detail of it was determined upon in advance of the successful manipulation but the solution was not worked out in detail and "accident" entered into the final process:

"Then a conspicuous part of one section caught the eye and from that time it seemed certain that it must have something to do with the solution. Work was kept on about that point. The final solution had some element of chance, I do not know just how I did it."—*Rd* (Heart and Bow).

"I tried bending the hinged circle and pushing it through the loops. This came as a perceptual impulse, a sudden glimpse of relations not fully worked out, but fairly clear for the first step."—*Rr* (Double Circle and Semicircle).

In the following transitional case the "accidental" impulse following on the preliminary analysis was caught in passage and was terminated purposely:

"The result followed a deliberate attempt to attack the loop end after recognizing the ring end to be impossible. The last step in the solution was a perceptual impulse with a flash of recognition of its similarity to a movement in a similar puzzle."—*Rr* (Semicircle and Chain).

(*d*) In the following cases the anticipatory analysis was much more complete:

"I knew how to do it as soon as I saw it. A visual image of the corresponding part of the Heart and Bow came on first sight."—*Ta* (Hook and Eye).

"Considerable uncontrolled manipulation was indulged in, but the ring was not gotten off in such manipulation. The random movement seems, however, in some way to have suggested a new way of looking at the puzzle, and the latter ended in its solution. The manipulation resulting in success was here the testing of a definite hypothesis."—*Wh* (Wire Maze).

"I began with rather aimless placing of pegs in order to get the hang of the moves . . . made several trials with a little analysis preceding each, but with no attempt at a complete analysis. Each time I would find myself brought to a stop without finishing and would have to analyze. Finally I analyzed the whole thing out beginning at the end, as follows: Since the hole marked 'Havana' is to be left open till the last (according to directions), the two holes distant two places from this can be left till the next to the last; the two holes distant two places from these come next in order. I followed back in this way till I saw which were the first that must be filled. My analysis worked promptly."—*Wh* (Lone Star War).

The cases given above were selected from a large number in the most of which the relations are much more complex. In the cases given as illustrating accidental solutions, various unsuccessful attempts to think the thing out or to follow some apparently promising suggestion had been made previous to the successful impulse. As has been previously stated, in most of the cases of accidental success the subject noticed the final position of the parts just after the solution, and so was in a position to eliminate a lot of movements concerned with other portions of the puzzle.

(2) Difficulty of Anticipatory Analysis. In the cases given as illustrating the anticipatory type of solution, it will be noticed that in the second and third the development of a plan of procedure followed upon a period of more or less random manipulation. The first illustration is that of an immediate and total solution. But this subject had already solved a puzzle very similar to the one in question. No cases were found in which a really novel puzzle was

"seen through" at once. One of the subjects was given the task of solving a fairly difficult puzzle without touching it. Three hours were spent in consideration of the puzzle before the subject felt sure that he had solved it. Despite the improbability of the references to the parts of the puzzle being intelligible to the reader a quotation or two from the subject's notes may throw some light on the difficulties involved. "I guess this last was wrong, for the folding ring would not drop from the staple to the split ring, as I had thought; and as it does in the case of the small staple, where it falls across without trouble upon the larger staple. But does it do this? It is hard for me to be sure. Simple as the question seems, I can not easily, without trial, make out the answer. But if I imagine a solid ring in the position into which I have supposed the folding ring to 'fall,' I see that it could not be got back into original position of the folding ring, and thence I conclude that I was mistaken in supposing that the folding ring would simply fall over on the large staple. . . . If I could see how to put the folding ring—supposed to be entirely off—on to the larger staple, I should have it. . . . I am anxious to put my plan to the test. I believe that I can see through it all right."

The subject then began the actual manipulation to test the theories worked out. "Immediately I met a difficulty, and see that I shall have to analyze further. The difficulty consists in the small ring getting in the way. . . . Got through the previous difficulty all right, but ran across another."—*Wh* (Double Circle and Semicircle).

The difficulties in picturing transformations in three dimensions are so great that few of the subjects tried with any great persistence to think the thing clear through in advance. Then too the impulse to manipulate seemed to be very strong, and this served to inhibit prolonged anticipatory analysis. "I started with the purpose of working by plan only, to solve it with anticipatory analysis, but got too impatient to see the parts in other positions to really test it."—*Ta* (Hinged Rectangle).

Even after a long practise series in which the puzzle had been successfully manipulated and the act reduced to one of skill, the subject was in some cases without any definite geometrical conceptions of the actual transformations. The necessary cues for movement had been learned in their proper order, but a unified conception had not been obtained. In one case of this sort—another subject working on the "folding ring" puzzle mentioned two paragraphs above—a low grade unity was obtained by conceiving the process as one of rhythmic reversal. This conception of the process came as a distinct experience and proved itself of value in the acquisition

of control of the part movements involved, but it was felt to be a rather superficial conception.

Although a number of the puzzles had familiar geometrical forms, such as circles, pentagons, triangles, etc., geometrical concepts of the usual school type did not seem to play a very large part in the actual solutions. The problem in most of the cases required more or less complicated transformations in three dimensions, and the mental construction of these transformations constituted a difficult task and one for which the more statical type of training received in the study of geometry seemed to furnish but little assistance. The experiences of everyday life with extensible objects came in a number of times. "If it were a rubber band and one end were held on the split ring just inside the loop of the large staple, the other end could be so moved as to compass at once the end of the staple and the end of the split ring . . . ." A few puzzles in two dimensions were tried where the problem was the construction of a figure. Part of the problem was to determine the sort of figure to be constructed. "I hit on the idea of a square from the result of one of the tentative combinations. This seemed a likely enough goal for the puzzle and I could approach the problem methodically, namely by making a table of the relative sides and areas, and seeing if the total area was such that it would be a perfect square of any side that could be got from combining the sides of the pieces. . . . The total area would thus be that of the side of a square with its side the longest side of the large triangle. I considered the other combinations of sides which would add up to 4, and experimented a little quickly getting the square." The two-dimensional problem was more susceptible of attack by geometrical methods than were the tridimensional.

There was no question that the puzzles demanding transformations in three dimensions constituted a novel problem and called forth untrained functions. That was suspected and was the reason for the selection of the material, but the extent to which it proved true was, nevertheless, surprising.

Is there a single function for "transformations in three dimensions" or are there numerous special functions? No experiments were definitely planned to test this point. It was noticed, however, that the ability to see the solution of a puzzle already known was affected by changing its position relative to the observer. The ability to manipulate it was, likewise, affected unfavorably, and the ability to take a puzzle apart could be highly perfected without that being true of the ability to reverse the process.

b. Significance of Scientific Methods.—Ideas of general methods

of procedure seemed to be more important in the attacking of new problems of the tridimensional sort than were the ideas of geometry. There was considerable difference among the various subjects, as to the degree to which variations were set up as explicit hypotheses to be definitely tested, as to flexibility of fundamental assumptions concerning the problem and as to the judgment used in their formulation, as to the employment of system and classification, and the developing of generalizations.

(1) Generalization. The value of explicit analysis and generalization based upon it is shown in the following case. In the Chinese-Ring puzzle there are numerous rings to be dropped through a loop in a rather intricate way. One of the subjects found that he could get certain rings off and not the others. Then it flashed across his mind that there was no apparent fundamental difference in the relation of the rings, and that if he analyzed a single case, a general rule could probably be developed. This was done and the puzzle solved. The subjects who did not develop an explicit rule in this case got into great difficulty when the number of rings was changed. Another subject not only analyzed out the general rule of procedure mentioned, in the first trial, but also developed a corollary from it as to the turning points, which saved him an immense amount of time and error as compared with the subjects who did not develop this at all or developed it so late in the series that erroneous methods of procedure had become well established.

(2) Grasping the Problem. There were great differences as to the readiness and precision with which the concrete problem was formulated. With the wire puzzles the subjects were simply given the general instruction: "Some part of the puzzle is to be removed." They were to "size up" the situation and form their own judgment as to the special problem in each case. In the Star and Crescent puzzle there is an interlinked star and an encircling star. The interlinked star is interlocked with an ellipse hinged in the center. The relation is that of two links in a chain, one link being jointed. The fact of one link being jointed does not change or affect the relation of interlinkage. The encircling star is the only thing that can be removed. One subject worked at this puzzle for 33,060 seconds—nearly ten hours altogether on five different days, and failed. At the close of the attempt he was asked to state what he was trying to do. He said that he was " trying to get the interlinked star off first and then the encircling star would come off of itself." Even here there was some elimination, since the subject said that it was impossible to separate the two parts of the hinged link, and that the solution was to be obtained by passing the star by some means over the hinge. In

the case of another subject in the course of 300 seconds all the essential points in the solution of the same puzzle had been determined. "'Star '2,' the encircling star, is the one to come off. Neither star will go through the other, therefore the encircling star *must* go over the crescent. The movable star *must* go down in the middle of that thing (the hinged link)."—*Br* (Double Star and Crescent).

(3) Classification and Elimination. In some cases the classification and methods of elimination used constituted the essential element in the solution, and were rather elaborate in character. With the construction puzzles where there were a good many pieces to be fitted into each other to produce a given figure—as a tridimensional cross—the number of possible combinations was exceedingly large. Of two subjects, both began with the classification of the pieces, as to symmetry of the notches, etc., but one developed a much superior method of elimination of possible combinations to that of the other. An extract from the record of the more successful subject will be given, and, although the reader may not be able to picture the transformations described, yet the method may become obvious. "Six pieces! No doubt it is a triaxial construction like the other one. [Subject here classified the pieces.] None have grooves on opposite faces. Does this mean that the pairs must face each other, *i. e.*, have grooves toward each other, as in the other puzzle? . . . Which are the pairs? . . . The pieces can be arranged in order according to the amount cut out, and perhaps this gives the clue to the order in which they have to be put in. For if, as is certain, the piece with the least cut out has to be the last to go in, may it not be that the piece with the most cut out has to be the first, because it will allow the most to be put in after it itself is in position? I suppose that it is not, however, the amount cut out of a single piece but of the pair that counts. . . . Any pair that you choose must be either mates or at right angles. This ought to be of some help for if this is settled for only two bars, the field of experimentation would be narrowed. The two that are alike can not form a pair, for. . . . Therefore the two that are alike must cross at right angles. Found a third which can not be a pair of either of the like ones, and thus had one of each pair. Now sought among the remaining two (excluding the plain bar) for one which would be the mate of one of the like ones. This was not such plain sailing, as the 'judgment' was involved. Judged largely by the space left. One of the selections promised well, and, following it up, I reached the conclusion." *Wh* (Six-piece Cross).

Elimination by Means of the Dilemma. In the case of another puzzle where the number of different possible combinations is 1,296,

and only one is the correct one, the method of elimination becomes crucial. For unless a person adopted a rigid method of recording what he actually did each time and did something different from what had been done at any previous trial, he would be likely to repeat the same fruitless combinations indefinitely. Of two subjects who tried this puzzle, both classified the elements and each tried at first an apparently promising but really fruitless method of combination. Then in the case of one subject the idea of exhausting the possibilities by means of a dilemma, with elimination at each division, occurred together with a happy insight as to starting point. The other subject failed to solve. In the case of this particular problem, the getting of a particular combination of figures on the faces of four cubes, an algebraical or "logical" type of analysis was much more applicable than in the case of the wire puzzles. Some transformations in three dimensions had to be imagined, but, in the main, substitutions could be made for this in terms of symbols which could be treated in a highly analytical fashion.

(4) Flexibility and Explicitness of Assumptions. One important difference in methods of solution was to be found in the flexibility of the assumptions employed as well as in the explicitness with which these assumptions were conceived. It had apparently never occurred to the subject who worked ten hours on the Star and Crescent puzzle to question his assumption that the interlocked star was the one to come off. That assumption suggested itself to him in some more or less accidental way, and was not itself made an object of criticism. The proper method of manipulation in its initial stages occurred accidentally a great many times in his work, but he seemed blind to all such possibilities.

(*a*) Uncritical Acceptance of Similarity Suggestion. Similarity to another puzzle in some cases acted in this negative way, the similarity being in regard to some non-essential feature, and being accepted uncritically. A number of puzzles were similar in having a ring which could be removed from a triangle, around whose point it hung, by folding the figure, leaving the triangle at the hinge, and moving the ring around the figure. The subjects solved the later specimens of this class very readily. Then a puzzle which folded and had a ring on a movable triangle, as in the other cases, but which differed from the others in that the triangle was to be left at the starting point and not brought to the hinge, was given to the subjects. They brought the triangle and ring to the hinge and attempted to leave the latter there. This made the solution impossible, but the attempt was persisted in and chance opportunities for the correct solution went unnoticed. One of the subjects

said after success came: "I thought of the other hinge puzzles as soon as I saw the hinge and thought that this would have to work in the same way." He spoke of a feeling of compulsion, that "the triangle just had to go to the hinge."—*Ta* (Wire Maze).

Another subject, after many attempts to solve in the accustomed way of the other similar puzzles, brought himself to question his method of attack. "Maybe I am working on the wrong line altogether. . . . Suppose there were no triangle, how would it come off? The rider is the only thing that holds it on. Hence, if I get rid of the rider in the right way, it will come off. . . . I wonder how it would do to leave the triangle at the starting point." The suggestion *as to leaving the rider at the starting point was the correct one.* It followed this conscious attempt to change his assumptions.—*Tz* (Wire Maze).

The Triple Horseshoe puzzle was given to another subject after he had solved the Star and Crescent. The Triple Horseshoe is similar in many respects to the Crescent puzzle, but there is an essential point of difference. This subject not merely noticed the similarity at once, but questioned it instead of blindly accepting it: "This reminds me of the Star and Crescent as far as the folding, but perhaps you *don't do it* that way. The problem is to get the small horseshoe off. You naturally can't pull it over the large one. There must be some other way of getting it, some feature here is quite different from the Star and Crescent. Let's take an entirely different start." The correct variation followed almost at once on this conscious attempt to get a change of attitude.—*Br.*

(*b*) Volitional Character of Assumptions. In some of the subjects the sticking to an assumption once started upon had a decidedly volitional character. The assumption had almost the force of a "fixed idea." Aside from the specific determination to stick it out on the line started, there is the strong influence of mental inertia, the dread of changing. The latter tendency comes out with especial strength in the case of the introduction of possible improvements in manipulation after a certain degree of success has been obtained. One dislikes to change even though he may realize that his present method may not be theoretically the best. He dreads to give up something that he feels confident of for something in which there is a possibility of not panning out. It is rather strange that a similar tendency should be found in the case of attempts that are not successful, in the first solution of a problem. The mental attitude becomes fixed in a more or less chance way, and there is hesitancy about changing even when the present method does not bring progress.

final movement. He did this, and then was asked to choose which major assumption and which minor under it he wished to test. He was able to eliminate some possibilities at once and choose the correct combination. He was then given the puzzle and solved it at once. In his previous attempt he had worked on the unfruitful hypothesis. Of course there is no mechanical way for the production of insights, but the conscious attempt to get into a different attitude, to realize that there may be other possibilities and to search for them, may be effective as a stimulus. In this case the happy insight followed at once on the demand for a rival assumption. The subject exclaimed suddenly: "Think I've an idea."—*Wh* (Bicycle puzzle).

The method of constant dichotomizing if carried to the bitter end might very well sidetrack a person from reaching the solution in the most direct manner, it might prevent his following a fruitful suggestion without delay and with confidence that manipulation or new suggestion would in some way bring the total solution. A fairly good chess player was asked to solve the Heart and Bow puzzle without touching it and with the method of exhaustion applied not merely to the major element in the solution, but to the details of manipulation at each step. As stated before, the thinking out of transformations in three dimensions with any precision is extremely difficult—at least it was for all persons tested—and in this case the subject found it impossible to carry some of the minor transformations through so as to decide definitely between rival hypotheses in advance of testing them. He outlined the correct line of attack, locating the critical point in the solution, but could not carry the processes through so as to be able to say precisely how he would get to that point. Consequently in the 5,000 seconds spent in this way a very important point in the manipulation at the "critical" part was not determined. The solution to that came the morning after as he was thinking the experience over.—*Ft* (Heart and Bow puzzle).

The subject stated that he thought the necessity for working out all the details in the exhaustive fashion required had impeded him in working out the essential point. The purpose of the experimenter in this case was that of testing not only how far the general solution could be attained in this way, but also the extent to which the entire technique of manipulation could be worked out in this completely anticipatory manner. The case serves probably, however, as an illustration of the difficulties in carrying over the algebraical type of solution to cases where the perceptual and image functions are essential but undeveloped. The total time for solution in this case was 10 times that of the average of the subjects who began manipulating at once, and 100 times that of the subject who analyzed the

variants of another puzzle which differed in the direction of certain wires, but were alike in manipulation; although it was suggested to the subject that there might be differences, none were noticed, until the puzzles were examined simultaneously and with the purpose of looking for differences. In the Hook and Eye puzzle a loop is to be moved around and into a reentrant ring. It can be moved in from one side but not from the other. Of nine subjects who solved the puzzle *only two made the discrimination in advance of the actual* difficulty. Of those two, one started to move in the wrong direction but retraced before getting into difficulty, and the other made the error as a result of inattention on the following trial.

An illustration from the records of one of the subjects concerning the discrimination in question will show the part that difficulty plays. The puzzle consists of a ring of wire with a reentrant end and a loop encircling the wire. The loop is removed by following the wire to the point where it becomes reentrant and then passing it over the reentrant end.

Trial 1: "I noticed the possibility of springing the ring apart inside of the square, and so thought of pushing the loop in there. I suspected rather than saw that this was the path to solution. Felt sure enough to start in that direction, and, as I proceeded, I saw into the last part of the process before I got to it."

Trial 2: "I tried first putting it around the wrong way, in the first trial I had not felt perfectly clear why I had put it one way rather than the other. Some mechanical resistance, not experienced in the preceding trial, made me suspect that I was wrong, and I looked more closely, but tried the other way and succeeded before clearly seeing why one way was necessary rather than the other, and saw that as the ring ended in the central prolongation it was necessary to push the rod off the end of the prolongation to get it off the ring."—*Wh* (Hook and Eye).

4. Discrimination and Imagery

This tridimensional transformation type of discrimination did *not seem to have any direct relation to the extent of visual imagery* as reported by the different subjects. The following table of subjects for whom the conditions were directly comparable will show the lack of correlation. The times for the first successes in the case of the Heart and Bow puzzle, first line, and the Star and Crescent, second line, should decrease from left to right if there were a direct relation between visual imagery and success, since the subjects are arranged in the order of their visual imagery from left to right, the subject at the left claiming to have no visual imagery whatever.

	Br	Bg	Tx	Rd	Tu	Fe
Heart and Bow	43	275	572	851	325	13,532
Star and Crescent	476	968	1,476	1,775	1,280	fail (1,660)

The relation indicated here would be that of a negative rather than of a positive correlation. It is not claimed that a negative correlation would hold if a larger number of cases were examined, but that visual imagery is not essential to the process. The subject who made the best record states that he is entirely without visual imagery. He is an instructor in logic and scientific methods and is without training in manual arts. Of the two subjects who reported the most vivid visual imagery one was very successful in dealing with the puzzles, especially in the detection of similarity of a given puzzle to earlier puzzles in the series, but the other subject required 400 times as much time to do the first puzzle and 200 times as long to solve a puzzle which was similar to it as did the first "visile." *Wh* seems to be practically destitute of visual imagery, but he solved fifty puzzles, some of them being done under difficult conditions, as with eyes closed, with his hands behind his back so that both lack of vision and unaccustomed tactual-motor conditions would prevail, and with vision but without the privilege of manipulating at all. His records were not included in the table just given as he performed the solutions in a different order from the other subjects. His records for these two puzzles were low, 54 seconds and 238 seconds, but this may have been due in part to transfer from earlier and similar puzzles.

As stated above, the writer finds the process of analysis, as far as his introspections have gone, to be of the same sort whether occurring in the field of perception or of imagery. He found great difficulty in the attempt to image the tridimensional transformations in advance of any movement, but, on the other hand, he found at certain stages a decided help in withdrawing the puzzle from sight or in closing his eyes and then attempting to work out the relations involved. The advantage in favor of the image seems to consist in the shearing off of irrelevant detail, and in the bringing of the total process within the time span. Since the tendencies to movement are more pronounced with perception than with ideation, the irrelevant detail mentioned is more likely, in the case of perception, to result in distracting movements. The writer's visual imagery is rather scanty in detail of objects, it comes part by part, and is poor in coloring; his "imagery" is shot through with motor tendencies. Since no motor trains were actually set going by the latter, they were not distracting, and they seemed to be of positive benefit in binding the different parts together. The building up of a unified image is,

however, no easy matter for the writer. In the case of a complex puzzle with balls strung on loops of string the final unified image was obtained after a long process of painful effort. The different stages in the transformation were constructed bit by bit and with the help of verbal imagery, both to stimulate the process and to fixate what had been obtained. Finally all the different steps were put together and the total process was given verbally. After it had once been obtained the process could be reviewed much more rapidly and surely than with actual manipulation.

The subject who had complete and ready visual imagery and who also succeeded well was rather reluctant to state the process of solution verbally; the verbalization followed upon the development of the visual imagery. In the eighth trial of the Chinese Ring puzzle he said: "I think I can do it again, but I can not tell how. I believe I have a visual image of the different stages of the process, but I can't describe the separate steps." In the eleventh trial he gave a verbal account of the main process. The subject with "no visual imagery" described whatever he was doing while he was doing it.

5. Attitudes

a. The Self-attentive Attitude.—That the puzzle situation was decidedly of the novel type is shown not merely by the slight capacity of the subjects to construct mentally the required transformations but also by their emotional attitudes. The first impression was frequently that the puzzle was impossible of solution, and the subjects spoke of feeling "hopeless" or "helpless." There was a fairly constant undertone of questioning as to whether the subject was not really very much inferior to ordinary people, especially when things were slow in opening up. Some of the subjects expressed the fear that the experimenter must be getting bored or that he would think them extremely stupid. An extract from one of the subject's accounts will illustrate the attitude.

"It seemed to me that if anybody had given it to me without saying that it was a puzzle (a bona fide one) I would have said it was impossible up to the last minute. I have a feeling now of loss of esteem. I had this all along because I couldn't do something which was made for people with ordinary brains to do. One conclusion that kept running through my mind all the time was that I had a subordinary brain. I couldn't help having a gleeful, self-satisfied feeling when it actually seemed to be coming off, although it was a surprise."—*Tz* (Chinese Rings).

An illustration from the sixteenth trial in the first practise series for the same subject will show much the same mental state of affairs springing up after the puzzle had been pretty well learned, when, all of a sudden, a new position had to be coped with, the novel situation breaking in on a fairly well established adjustment. "The heart was not slipped over the end of the bar (it would then have been off) but was pushed back on the same side and instead of the heart falling free it was in an entirely new position. This had to be studied out before the heart could be freed. I felt chagrined and became nervous, feeling that the time was being wasted. I felt a dislike to waste more by studying anew the manner of releasing the heart from this new position. But I knew this was necessary, so I gave up almost wholly the idea of time and the *how* became uppermost. I became then less nervous."

This nervous self-consciousness seriously lowers efficiency both in the first solutions and in the process of skill acquisition. When the break occurs even late in the practise curve all the old errors, apparently outlived, crop out again with an almost fatal regularity and by their reappearance gain new strength.

The latter part of the last quotation illustrates the more or less complete change from this self-conscious attitude to one of absorption in the thing to be done. The same subject after solving his eleventh puzzle said: "I did not hurry, made up my mind not to get flustered—a different attitude toward the puzzles now than at first. I look at them now as I would a problem in mathematics, *i. e.*, I feel that I have some fundamental principles with which to attack them. I had made up my mind before not to get rattled but didn't hold to it. There seems to be a change."—*Tz* (Wire Maze).

This reversal of attitude was stimulated and brought about in various ways:

1. A chance success with the first puzzle in the case of one subject resulted in a complete change of attitude toward the remaining puzzles. The chief factor here seems to have been the removal of the conviction that the puzzle was impossible of solution. This conviction could not be overcome by the assurances of others; actual personal success, although a chance one, was necessary in this case.

2. The voluntary holding before the mind of the value of the objective attitude and the conscious attempt to get it seemed efficacious in many instances. This was true not merely in getting the first success with a given puzzle, but also, and strikingly so, in the acquisition of skill in manipulation.

3. After several puzzles had been successfully dealt with confidence was developed in a number of the subjects that the new puzzles

would not be wholly unlike the old. They felt that they had a body of rather closely related experience which could be used in attacking the new problems. At the beginning of the series the opposite conviction was noted, that the subject had nothing with which he could directly attack the problem.

4. Confidence was developed also in connection with the belief that the subject had some general methods with which to deal with novel situations. Under this head might be mentioned belief in the value of general logical and scientific methods, and the belief in the self as essentially variable provided favorable conditions were supplied. This last factor was noted only in the case of a few subjects.

Knowledge that another subject had succeeded where a given subject had failed in some cases seemed to stimulate the subject, to bring increased confidence, and in others to result in depression and an apparently lessened capacity to vary. In the latter cases the subject's attention seemed controlled by the idea that he was much inferior to others and in the former cases by the idea that it couldn't be so very difficult after all.

In concluding this section on the Self-conscious Attitude it may be stated that one of the most striking phenomena of the whole investigation was the large place in the consciousness of the subjects occupied by this idea of the self being on trial, usually with an accompanying apprehension that it was proving sadly deficient, and a correspondingly insistent demand for social appraisal. The experiments were not planned to encourage this socialized attention but rather to minimize it. There were almost constant indications of its presence, however, and occasionally it cropped out with a vigor which betrayed its latent strength. Thus, one sedate superintendent of schools, who was acting as a subject, suddenly broke out with, "You simply must tell me how I am getting along in comparison with the others."

b. The Suggestible Attitude.—In two of the subjects there seemed to be a special sensitiveness towards any movements of the operator which might give an indication as to the course to be pursued. In such cases as this there is a lack of confidence in the self but the attention is directed not to the self but to some other person. The center of gravity, if one may so describe it, of the responsibility is located elsewhere and the suggestions, intentional or unintentional, of the other person or persons concerned are accepted uncritically. This tendency was noted by the writer in his own case in novel situations of a more distinctly social type, such as business transactions of an unaccustomed sort, or other similar cases where persons instead of things were to be dealt with and where the other

person was felt to have superior information as to the matter in hand and the self to be deficient.

c. The Problem Attitude.—In contradistinction from these two attitudes, which are certainly not favorable to efficiency, a third attitude, conducive to efficiency in dealing with novel situations, might be called the problem attitude. A tentative outline sketch of such an attitude will now be given. It would be an attitude of self-confidence as opposed to the self-distrust of the two preceding ones. The self-confidence would not be one of sluggish complacency however, but would be expressed in a high level of intellectual activity, of attention.

Attention would be directed to the thing to be done rather than to appraisal of the self. This does not mean that attention might not be directed to the analysis of some successful movement made by the self, whether in terms of resident or remote cues of action, or some general condition of effective response by the self, for in these cases the attention is on the problem of working out the mechanism of control.

There would be a freedom towards variations and a confidence that the organism would furnish them.

There would be a corresponding and compensating tendency toward critical evaluation of variations, a flexible holding of assumptions and suggestions and a rigid testing of them, ideational or manipulative, whether these suggestions emanated from the self or from a "prestige-person." The various factors entering into this attitude, self-confidence, high-level attention to the thing to be done, openness toward novel lines of attack, and critical evaluation of suggestions from whatever source, were noted in the puzzle series to be connected with efficient forms of response.

CHAPTER IV

Puzzle Material and Tests of Intelligence

As possible tests of comparative intelligence Cole[1] has used, on the basis of Kinnaman's[2] results and his own with animals working with puzzle boxes, the ratios of trials 1 to 2. The ratio for Kinnaman's monkeys was found to be 2:1 and for Cole's raccoons to be 3:2. The ratio in the case of human subjects working with puzzles of the physically analytical as opposed to the physically constructive type was found by the writer to be 7:1. This result was obtained by adding together the first times of all comparable solutions for thirteen different puzzles, there being seventy-three such first solutions in all, and finding the ratio of this sum to the sum of the times for the second trials concerned. The question as to the significance of this ratio will now be discussed, the value of certain other possible measures will be considered in the light of the results obtained with the puzzles, and certain general considerations bearing on the problem will be adduced. The use of ratios will be considered from the standpoint of measurement of individuals within a single group and from that of the comparison of different groups.

1. Intra-Group Measurement

a. Ratio of Trials 1 and 2.—If the individual ratios of trials 1 and 2 for the seventy-three cases mentioned be calculated, the time of each first trial being used as the numerator and its corresponding record for trial 2 being used as denominator of the ratio in question, the range of variability exhibited is striking. The maximum ratio thus found is 134:1 and the minimum ratio is inverse, 1:4.5. If the first and third trials instead of the first and second are used, the extreme instances are further apart, the upper ratio is now 200:1 and the lower is 1:13.4. The group, or inter-group, ratio would thus be decidedly misleading if taken without some measure of variability within the group. Incidentally the inverse ratios show that the process of learning manipulations by human beings is not always a case of getting a clear idea as a result of a single success with a consequent sudden drop in the curve, but is at times similar

[1] L. W. Cole, *Jour. Comp. Neur. and Psych.*, Vol. XVII., p. 211.

[2] A. J. Kinnaman, *Am. Jour. Psych.*, Vol. XIII., pp. 126–127.

b. Absolute Measures.—It would seem from the illustration just given, that ranking by absolute times would obviate the difficulty just raised as to possible misrepresentation of the kind of analysis involved. That this is not the case as applied to the absolute times for trial 1 will be seen from the following illustrations. In the case of the puzzle referred to above, the Heart and Bow, the time of one accidental first success was forty times that of another. While the times for accidental success might in a way measure the relative variability of the subjects and so be of value, it would be a very unprecise form of measurement, as it would be determined by the chance order as well as by the number of the variations.

The time for later trials is often greater than for trial 1. In one case of accidental first success with the Heart and Bow puzzle the time for trial 2 was three times that for trial 1, the times being respectively 575 seconds and 1,885 seconds. In another case, Star and Crescent puzzle, the time for trial 3 was thirteen times that of trial 1, the times being (1) 132 seconds, (2) 590 seconds, (3) 1,775 seconds.

A third illustration is given in the fact that an accidental solution is often shorter than one that is planned. The time for the accidental success mentioned in the previous sentence, 132 seconds, is less than one third the time for one success reached by analysis, 476 seconds, and less than one ninth the time of another, all for the same puzzle.

While the time for trial 1 might be thus largely affected by accident, the times for trials later than this would reveal the kind of analysis performed in trial 1 whether the success were accidental or planned. A successful variation may be unpremeditated and yet be caught on the wing by attentive analysis, and consequently result in a drop in time in the succeeding trial. Of course accidents may be repeated without analysis having taken place, but this seems to have been a rare occurrence in the puzzle series. As measures of the early part of the curve the following times have been used: for trial 2, for the median of trials 2–6, and for the lowest of trials 2–6. The following table presents these measures for nine subjects, whose results are comparable, for the Heart and Bow puzzle. The table includes also a grading as to the kind of analysis made during the first trial and as to the degree to which it was accidental, and, further, the times for trial 1, and the individual ratios of trials 1 and 2. The gradings as to analysis are based upon the subjects' own accounts and also upon the operator's records of their behavior. The letters under the caption "Anticipation" in the table refer to the degree to which the solution was a result of anticipatory analysis. The

grade "A" means that the solution was accidental. The grade "C" means that a certain portion of the puzzle was selected as the central element, and that the solution followed on this focalization. Four grades were used in grading solutions as to anticipatory analysis, but only two grades were found with this puzzle. The numbers under the term "Analysis" stand for the degree to which the analysis was carried as a result of trial 1 and preparatory to trial 2. A very high percentage of the solutions is seen by the letters to have been accidental, viz., 6 out of 9. The subjects are arranged in the order of the times for trial 2. A second table presents the results of the preceding table in terms of relative rank only and includes in addition a ranking as to errors and a summation rank. The grade as to errors was determined by taking into account both the number of errors and the point in the curve where they disappeared. The lower numbers indicate that the errors were few and disappeared early. The summation rank is given in two forms, a total summation of all the columns, and a summation of all except for trial 1 and the ratios of 1 and 2.

TABLE I

	Ratio 1 and 2	Trial 1	Trial 2	Ratio of Trial 2 to Standard	Median 2-6	Average 2-6	Smallest of 1-6	Anticipation	Analysis
Br	6.0:1	43	7.0	1.0	8 0	8.2	3.2	C	1
Ta	27.0:1	325	12.2	1.7	9.4	8.9	5.9	A	2
Rd	49.0:1	851	17.3	2.4	19.2	26.7	16 0	C	4
Bg	5.9:1	275	46 6	6 6	16 0	18 2	5 5	C	3
Tz	2.7:1	572	212.4	30 0	18.4	54.8	8.2	A	3.5
Mt	1.4:1	351	256.4	36 6	50 0	104 0	27.0	A	4
Ry	20 0:1	5,203	260.0	37 0	214 0	228.0	143 0	A	4
Fe	38 6:1	13,532	351.0	50 0	261.0	233 0	40 0	A	4
Po	0.3:1	575	1,885 0	269.0	45.0	404 0	18.0	A	4

Consideration of the tables will show that the grading by the medians of trials 2–6 agrees most closely with the grading as to kinds of analysis, as to errors made, and to the total rank. It will also show that grading as to times for trial 1 and as to ratios of trials 1 and 2 depart widely from the standards mentioned. Since the median agreed more closely with the above than did the times for trial 2 or for the averages of trials 2–6 or for the lowest of trials 1–6, and since it is more easily found than the average, it was adopted as a measure of the early part of the curve.

c. Ratios with a Common Numerator.—If ratios of trial 1 to some other measure of the early part of the curve be desired, the use of a

TABLE II

	Ratio 1 and 2	Trial 1	Trial 2	Median 2-6	Average 2-6	Smallest of 1-6	Analysis	Errors	Rank Columns 2-6	TotalRank
Br	5	1	1	1	1	3	1	1	1	1
Ta	3	3	2	2	2	1	2	2	2	2
Rd	1	7	3	5	4	5	5	5	5	4
Bg	6	2	4	3	3	2	3	4	3	3
Tz	7	5	5	4	5	4	4	3	4	5
Mt	8	4	6	7	6	7	5	7	6	6
Ry	4	8	7	8	7	9	5	9	8	8
Fe	2	9	8	9	8	8	5	8	9	8
Po	9	6	9	6	9	6	5	6	7	7

single numerical standard as numerator for all the fractions would have the advantage of giving the same rank as the absolute measures themselves and of furnishing further indications as to the sort of mental processes involved. The following table gives the ratios of the highest individual time for trial 1 to the medians of trials 2–6 for the same puzzle and subjects as the tables just preceding. The highest time was 13,532 seconds, *Fe*.

TABLE III

	Br	*Ta*	*Ed*	*Bg*	*Tz*	*Mt*	*Ry*	*Fe*	*Po*
Ratios of 13,532 seconds to times for medians ..	1,691	1,440	705	846	735	271	63	52	301
Individual ratios	5	35	45	17	31	7	24	52	13

It will be seen that, while *Fe*'s ratio is highest when the individual times for trial 1 are used as numerators, it is lowest if a constant numerator is employed.

d. Comparison of the Practise Curves as Wholes.—The measures so far presented concern chiefly the first few trials of the curve, and measure the readiness and completeness with which the main problem is solved. Success in handling the puzzles in minimum time depends, however, on the solution of minor problems of manipulation. Some convenient test is needed for the comparison of the curves as a whole, since it is at times not convenient to present the entire curves, and since it is often difficult to make the comparison even then. The following table is prepared by sampling the curves at various points by means of the medians of a few trials at those points. The columns present respectively the medians for trials 2–6, 6–10, 21–25 and 39–50, and a summation ranking for the whole curve. As compared with the previous tables this one is incomplete as it was not possible to secure fifty trials with all the subjects. The

most marked case of change of rank as between this table and the previous ones is that of *Tz*, who here ranks number 1. The rise in rank in his case apparently resulted from an explicit analysis of the minor problems of manipulation.

TABLE IV

Medians	2–6	6–10	21–25	39–50	Summation Rank
Br	1				
Ta	2	2	2	2	2
Rd	5	5	2	3	4
Bg	3	3	4	4	3
Tz	4	1	1	1	1
Mt	7	7	3		
Ry	8	8	6	5	5
Fe	9	6	5		
Po	6	4			

e. Perception of Similarity as a Test.—A test of the mastery of a given puzzle problem may be found not merely in the ways already indicated but also in the readiness with which a related problem is solved, and in the nature of the mental processes involved. Six of the nine subjects listed above were tried after several days' interval with a puzzle closely similar to the Heart and Bow. No suggestion was given by the operator as to there being any relation to a previous puzzle. The subjects were graded as to their standing in trials 1 and 2 in the new puzzle, the Hook and Eye. Their rank is as follows:

Br	*Ta*	*Rd*	*Bg*	*Tz*	*Fe*
3	1	5	4	2	6

The ranking agrees fairly well with the ranking gained by use of the practise curves of the Heart and Bow puzzle.

2. Inter-group Measurements

The comparison of groups by means of the ratios of the averages for the first and second trials would seem to be open to the same objections as the comparison of individual ratios within a given group when both numerator and denominator vary. Valid intra-group comparison seems to necessitate the use of a constant numerator and the same principles would apparently apply to inter-group comparisons. As compared with an animal group the different puzzles and subjects might be taken as a homogeneous group, and it was so considered in determining the group ratio of 7:1. But within this one group there was a wide variation between the ratios of the averages of trials 1 and 2 for the different puzzles, the ratios ranging

from 1.5:1 to 40:1. The times for trials 1 and 2 respectively were averaged for four selected subjects for eight different puzzles. The ratios are given in the following table.

Heart and Bow	7 :1	Cross and Ring	10 :1
2 Star and Crescent	4 :1	Hinged Rectangle	11 :1
Chinese Rings (4)	2.5:1	Hook and Eye	2 :1
Chinese Rings (6)	3 :1	Semicircle and Ring	1 :1

The subjects were *Bg, Rd, Ta, Tz.* The puzzles are arranged in the time order of their performance. The higher ratios belong here to the puzzles in which analysis of the "locus" type played the largest part. The lowest ratios belong to the puzzles in which the transformations were especially difficult to construct, as the Chinese Ring and the Semicircle and Ring. The ratio is low for the Hook and Eye puzzle because of its similarity to the Heart and Bow. This similarity resulted in low initial times.

The range of variability in ratios here with a narrowly selected group of subjects and with puzzles all of the same general class is twice that of ratios used in the comparison of men and animals. It is not maintained that a high ratio always indicates a "locus" type of analysis, as that is not the case, but that the two may be found together, and that for that reason inferences from ratio to mental processes are insecure unless the nature of the problem is specified.

A test for inter-group comparison making use of modifications of a given puzzle form is touched upon in the following section.

3. General Conditions of Comparative Tests

Even if the comparison were confined to members of a group working with a single puzzle, certain general factors would need to be either equated or evaluated before the measure secured could be taken as a measure of intelligence. These factors have been for the most part treated in other chapters and will be but briefly touched upon in this connection.

a. Physical Condition.—Thus *Br*'s efficiency in getting first solutions was apparently seriously impaired by a necessary change from a favorable to an unfavorable time of day in case of one of the meetings. He complained that he could get "no insights."

b. Degree of Development of the Fundamental Function.—As stated in a previous chapter the capacity to construct transformations in three dimensions seems to be relatively undeveloped. The two-dimensional problems seemed much easier of solution. The writer had intended to examine into the effects of manual training and of the study of descriptive geometry by taking series with sub-

jects both with and without the training in question but otherwise as homogeneous as possible, but he has not been able to do that as yet. A single manual training teacher was tried with a few of the puzzles and she did very well but that may have been due to other causes. Whether there is a single function of the sort referred to or whether there are many was not determined, but it was noted that presenting the puzzle in a new position interfered with readiness of solution, that learning to do the puzzle one way did not necessarily bring the ability to reverse the process, that pronounced success with one type of puzzle was not always accompanied by success with puzzles of a different type.

c. Concrete Related Knowledge.—*Wh* was given puzzles involving all the fundamental principles of a new and complex one, the Hinged Rectangle. He solved this the first time in 45 seconds. The best time made by a person who had not solved the puzzles involving the principles was 1,346 seconds; the puzzle was a difficult one and two subjects failed to get it. The subjects who had been given some but not all of the elements of the complex puzzle ranged in times from 157 seconds to 5,132 seconds. Their records are given in the following table.

Bg	*Tu*	*Tz*	*Mc*	*St*	*Co*	*Rd*
156.8	362.4	375	964 6	2,189	3,262	5,132

d. General Methods.—Ideals of scientific method seemed to be effective in proportion to the novelty of the experience. The boys, without scientific training, failed to develop a general rule or formula in the case of one puzzle where complications were introduced necessitating changes in manipulation which could be predicted if a general formula of solution had been developed for the solution of the puzzle in its first form. This generalization was made by those with scientific training The boys did not show themselves much if any inferior in the use of concrete related knowledge as supplied in earlier and similar puzzles.

e. Attitudes.—This topic was discussed at the close of Chapter III.

If these and possibly other important factors were under control, we might hope to get some test for intelligence which would measure the variability of the subjects in both qualitative and quantitative terms. The term variation is used to include not merely the coming of a suggestion or impulse but also its evaluation. One of the best ways of doing this seems to be that of training the subjects with a puzzle of a given type and then studying their capacity to use this knowledge in dealing with more or less thoroughgoing transformations of the principle involved. The table just given shows the

range of facility in utilizing related knowledge in dealing with a new case. The following table for the Hook and Eye puzzle gives further detail. This table has been presented already but in the form of relative rank only. All the subjects had solved a closely similar puzzle previous to solving this.

TABLE V

HOOK AND EYE

Ta	*Tz*	*Ey*	*Br*	*Bg*	*St*	*Co*	*Fe*
7.4	12.0	29.0	44	117.4	164.2	448.2	1,455.4
4.4	3.9	62.4	7	5 6	4.4	4.0	1,869.0
5.0	2.8	13.7		4.6	2.8	3.4	617.4
2.8	1.8	11.7		3.0	3.0	3.2	25.8
2.6	1.8	6.5		5.0	2.4	2.6	26.8
2.5	4.2	3.8		4.2	2.3	2.6	23.8
2.3	1.8	3.0		3.6	2.6	2.2	16.0
2.3	3.3	2.9		3.6	2.2	2.4	5.4
1.8	2.9	2.8		3.8	3.0	2.0	6.8
1.9	1.6	4.9		5.4	2.2	2.4	5 4

The two subjects making the best records, *Ta* and *Tz*, stated that they thought at once of the Heart and Bow puzzle. *Fe* had a vivid mental picture of the latter puzzle, but her attention became fixed on an irrelevant feature and she made no use of the experience. This result illustrates rather powerfully the difference between having the related experience, or even recalling it, and the using of it in dealing with a problem.

By varying the number and complexity of modifications of the original form of problem, the subjects could be distributed according to their capacity to use related knowledge, and a comparison between groups would become possible in terms of modifications mastered, even when it would be difficult to compare the difficulties of the original problem. This seems to promise especially well where the groups are widely separated as with animals and men.

CHAPTER V

The Place of Analysis in the Practise Curve

It was suggested in the preceding section that not merely the first few trials, but also the whole course of improvement in practise, might be used as a "test of intelligence" provided the many and seriously complicating factors involved were borne in mind. According to the results of Book and of Swift the course of practise would hardly seem suitable for such a purpose. They found, to be sure, that drops in the curve were very largely dependent on variations in method, but they also found that these variations were most effective if allowed to grow into habits of action without being specifically attended to. This is quite possibly an overstatement of their position, but, with that understanding, it may serve to define the question more sharply. To quote:

Swift, "Mind in the Making," p. 213: "It is suggestive that in all these experiments the method by which the reaction was improved was hit upon unconsciously. The learner simply tried to do the thing upon which he was working, and, in the process, he found himself using an improved method, and the new acquisition was always well along before it was discovered. . . . In order to test the matter further, the writer has since tried the experiment of learning to handle a punching bag skilfully, and here also it is quite clear that all of the delicate movements by which the bag is made continually to rebound with a rapidity that the eye can not follow, were happened upon quite unconsciously. There is a subconscious utilization of experience."

Book, "The Psychology of Skill," p. 171: "The new adaptations or forward steps were made quite unintentionally so far as the subjects were concerned. They were simply fallen into when the conditions were favorable for making a forward step and were executed marginally for some time before the learners became aware of their presence and value for the work. When the advantage of the new method had been noticed it was generally thereafter made use of purposefully though, even then, consciousness seemed to be more a hindrance than a direct help."

The results of the practise series with the puzzles seem to show, however, that with such material, at least, the method of conscious

control is the efficient one. A large percentage of the motor variations come, to be sure, without definite anticipation; they are started and perhaps well along in their course before their significance is realized; but their value seems to depend rather directly on their being noticed, purposely tested, and adopted or rejected as the case may be. The value of the explicit analysis of the variation is, of course, most pronounced when the conditions are changed, but the conditions are rarely precisely the same, however careful one may be in the attempt to make them so.

1. Percentage of Drops due to Conscious Variations

One hundred and twenty-eight curves were examined and the drops in time marked. Reference was then made to the accounts of the trials concerned as kept by operator and the subject. If it were found that at the point in the practise curve where a given drop occurred a variation in method had been introduced by the subject and reported by him, and if the variation were known to have some significance as a means of control, the drop was recorded as due to the conscious adoption of a variation. Variations often appeared in a single trial and were reported by the subject but without becoming established. In some cases variations were introduced which apparently resulted in a rise in time. The determination of the cause of a single drop in the curve is not a simple matter, and there is, very likely, a considerable range of error in the determinations, and the percentages given should not be taken as exact, but as standing for an area rather than a point.

Number of practise curves	128
Total number of drops	308
Number of conscious variations coincident with drops	222
Percentage of drops due to conscious variations	70

In certain cases only the objective record was kept. Variations in method were noted, and, if the subject brightened up at a certain point, moved directly and precisely, and maintained the variation after that time, the variation was marked, "objectively purposeful." Such cases are not included in the percentage given above. If they are added, and the operator feels confident of the interpretation of the objective signs, as borne out by the cases where the subjects' records were also available, the percentage would be increased to 78.

2.6 per cent. of the drops were credited to variations in method for which there was neither objective nor subjective record indicating that the variation was the object of attention on the part of the subject. 5.5 per cent. were put down as due to increased atten-

tion during the last ten trials of the series of fifty, the final spurt. 3.6 per cent. were attributed to a uniformity of method, the absence of disturbing variations or oscillations between several different methods which sometimes occurred. The rest of the drops were put down as unaccounted for. These last amounted to 12.5 per cent. of the total number. If they were all counted as cases of drops due to accidental variations, the per cent. for unconscious variations would be 12.5 plus 2.6, or 15.1. There was no evidence that they were due to this cause, and the supposition is made simply to try to get some statement in terms of limits. The extremes in comparability of per cents. would thus be:

A	Per Cent.	B	Per Cent.
Conscious variations	78	Unconscious variations	15.1
Unconscious variations	2.6	Conscious variations	70

The analyses of the variations differed in the ways described in Chapter II., in time of occurrence in relation to course of the variation, in explicitness, completeness, causal, local or merely mnemonic character, etc. These various forms of analysis are of very different value, but they all agree in that the general nature of the process involved is that of setting up an hypothesis and more or less critically testing it.

2. "Curves" Illustrating Significance of Conscious Variations

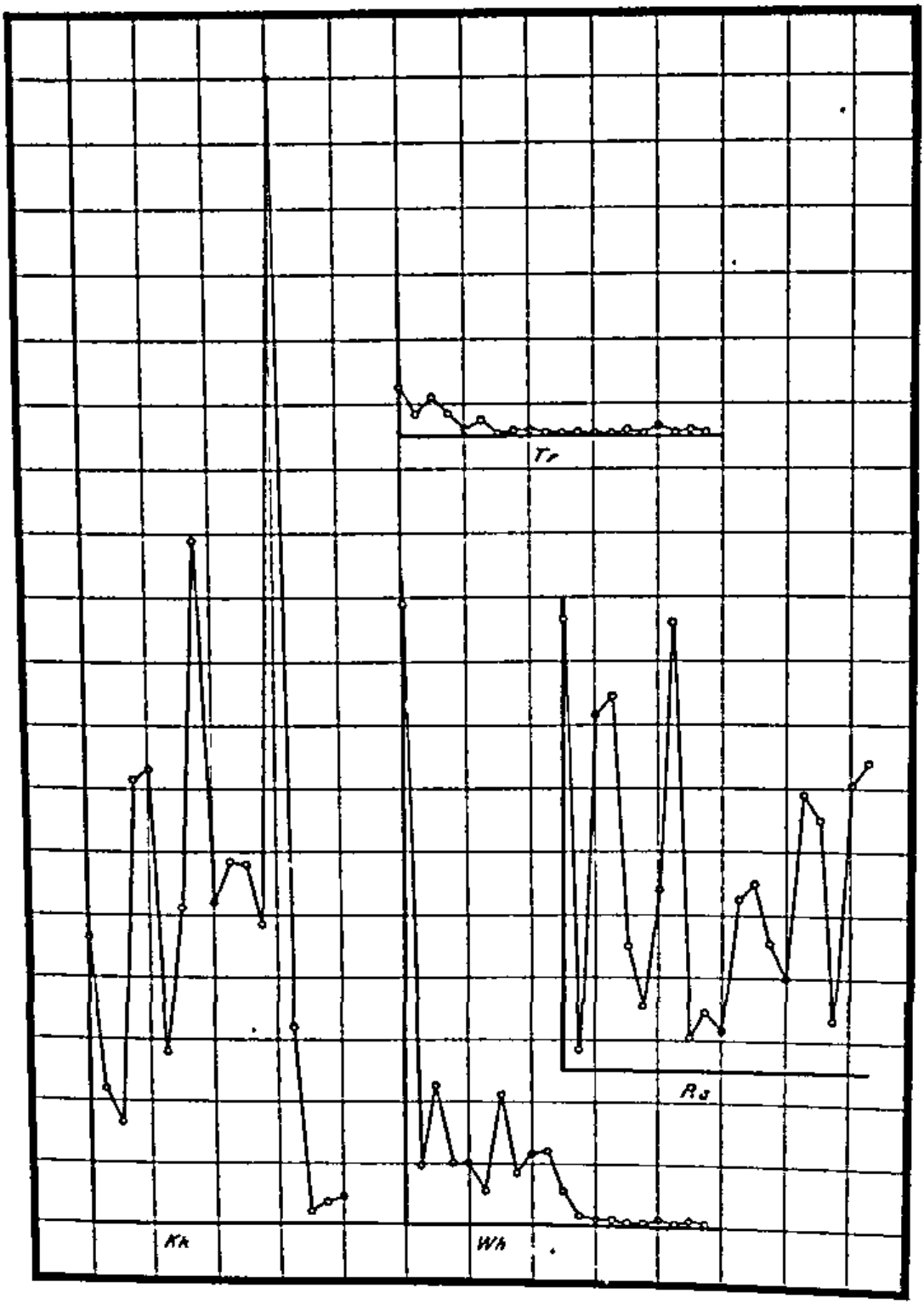
(1) The first illustration consists of the records of the first fifteen trials of the subjects *Rd* and *Tz* with the Star and Crescent puzzle.

TABLE VI

	Rd	*Tz*		*Rd*	*Tz*		*Rd*	*Tz*
1	132.0	1,476 0	6	63 6	25 0	11	42.0	31.4
2	590 6	241.0	7	109 6	50 0	12	14.8	22.4
3	1,775.5	44 2	8	43 2	28.6	13	28 0	66 6
4	278 4	33.8	9	70 0	37.6	14	9.0	35.4
5	750 0	32.7	10	28.6	24 6	15	14.6	29.0

In the case of *Rd* it will be noticed that instead of a drop after trial 1, there is a rise, and that the times remain higher until trial 6. The first success came in such a way as to render discrimination difficult. There are two stars, but only one can come off. They were closely associated by chance in the first success. In trial 3 subject realized that the stars must be kept apart, but did not work out a technique for it till the latter part of trial 5. The very fact that she had difficulty after succeeding easily in trial 1, made her nervous,

PLATE II



TWISTED NAILS—PUZZLE No. 19

Scale: smallest division = 4″. *Kk* and *Wk* as described in text; *Tr*, normal curve; *Rs*, distraction.

TABLE VII

	Wh	Kk		Wh	Kk		Wh	Kk
1	397.0	186 0	7	82.4	213 4	13	3.6	720 0
2	38 4	87.6	8	34 2	436.6[1]	14	3.2	127.0
3	91.0	65.0	9	45 0	207.4	15	2.6	7.0
4	40 0	287.0	10	48.6	234 6	16	2.6	16.0
5	39 4	291.6	11	21.6	232 0	17	2.8	16.0
6	20 4	112 0	12	6 6	194 0	18	1.2	17.0

[1] One hour later.

important rule concerning details of manipulation was worked out. There is a second sharp break in the curve at this point.

Kk failed on the thirteenth trial after spending a longer time than on any previous one. He was then asked to look at the puzzle. The remaining trials are with vision. The lack of vision proved a more serious hindrance for *Kk* than for *Wh*. The latter was able to analyze in terms of tactual motor experience. The former analyzed the movement only after he was permitted to use his eyes. The latter case shows that mere repetition of the success was not sufficient for formation of habit.

(3) The following six records from the Heart and Bow puzzle show the results of conscious variations at different points on the curves and the marked contrast between different series as to the quickness and thoroughness of analysis.

The "curves" in the accompanying table (Heart and Bow) will be treated individually in the order right to left.

Fe. The drop from trial 1 to trial 2 was due to a locus analysis. There is little improvement till trial 5. To quote from the subject's record for trial 3: "I did not get it with a purpose. Have a general notion of where to work; was trying to make a mental picture of how the rod should be when you took it away." At the end of trial 4 the subject noticed the position carefully as the puzzle came apart again by accident. "I got a good mental picture that time. Now I know it." There is a sharp break in the curve at this point and it does not rise again to the previous level. In the seventh trial the essential process was verbally described. The later variability was connected with the process of orienting the puzzle, the subject shifting from one method to another.

Mt. The first successes were due to chance and the slow drop in time in trials 1–3 was "locus" analysis. Trial 1: "I have no idea in the world how I did it. I remember moving the loop of the heart about the end of the bar, and the two pieces suddenly came apart. I think that I can do it sooner next time, not because I know just how to do it, but I remember the parts of the puzzle which I brought

together in the first success." Trial 2: " . . . do not yet know what movements to make." Trial 3: "Success was still largely chance; did not anticipate except that I knew there was a certain part of the

TABLE VIII

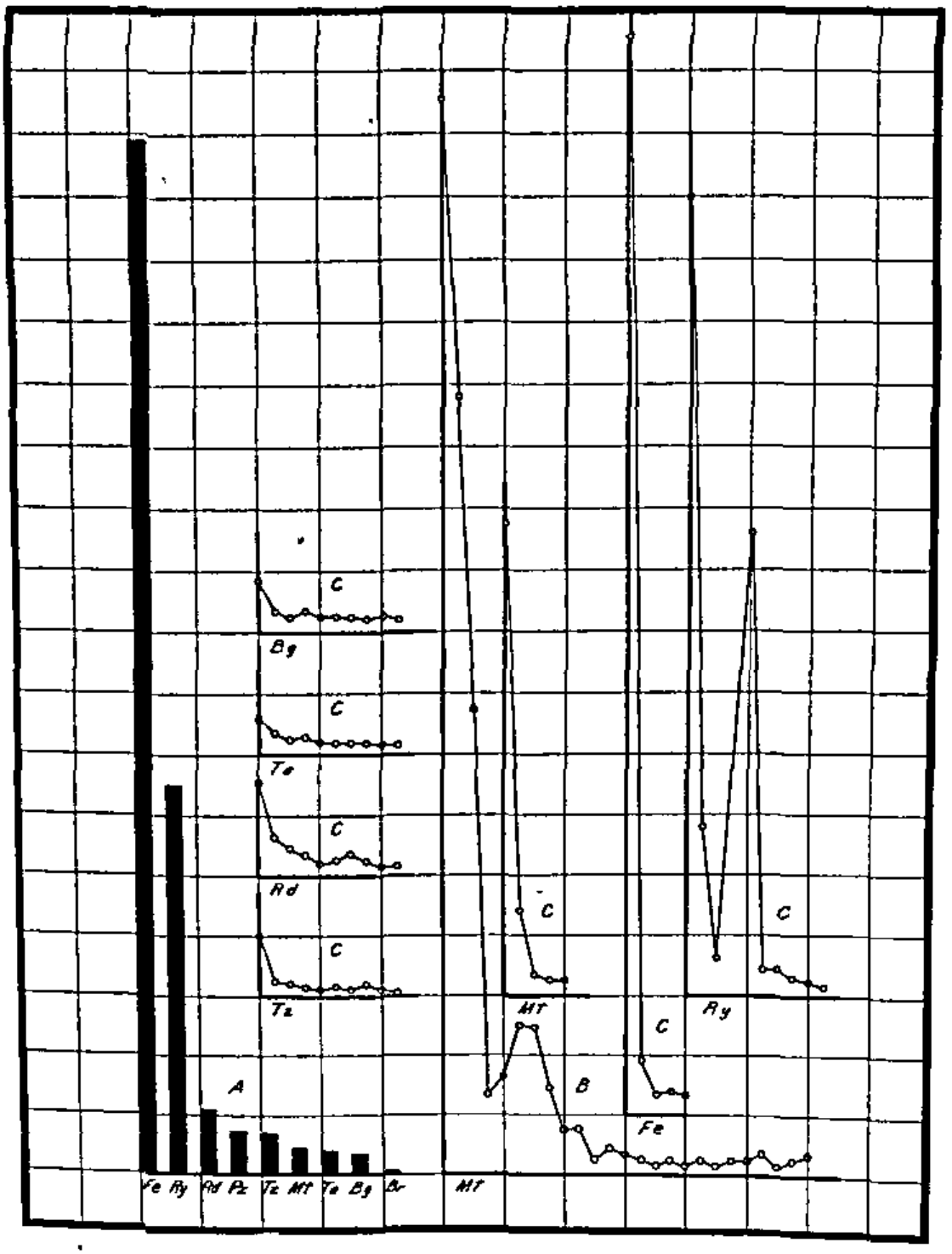
HEART AND BOW PUZZLE

	Tr	*Tu*	*Ey*	*Rd*	*Mr*	*Fr*
1	572 0	325.0	5,203 0	851.0	351.0	13,532.0[2]
2	212.4	12.2	260 0	17.3	256.4	351.0
3	18.4	8.4	196.0	50.0	155.0	437.4
4	20.8	5 0	214.0	16 0	27.0	261.8
5	14.4	14.4	331.0	31.1	33.0	40 0
6	8.2	9.8	143.0	19.2	50.0	65 0
7	5 6	7.0	54.0	11.2	49.6	15 0
8	6.6	6.2	24 0	20.2	28.0	30.6
9	4.0	4.8	56.0	13.0	13 6	18.8
10	3 6	10 8	58 0	10 4	13.7.	10.2
11	6.0	5.0	21.0	13.4	6 0	6.5
12	4.2	5.6	40 0	12.0	9.5	12.8
13	3.6	4.3	12.0	7.0	8.0	6.7
14	4.0	8.0	13 0	9.0	5.0	10.6
15	3 4	4.6	13.0	7.0	3 6	6.0
16	28 0	6.0	101.0	7.8	4 8	7.0
17	3.6	5.9	118.0	7.6	3.6	10.6
18	2.8	6.8	19.0	10 0	4.4	7.8
19	2.2	4.7	32.0	7.0	3.3	8.7
20	2.4	4.1	62.0	5.4	4.5	6.5
21	2.3	3.9	189.0	3.8	4.8	7.0
22	2.0	3.5	244 0[3]	3.6	7.7	6.0
23	2.0	4.1	152.6	6.1	3.2	7.0
24	1.8	6.8	19.4	6.1	4.7	7.0
25	3 0	4.3	128.0	4.1	6.2	7.4
26	2.4	3.6	172.0	4.3		
27	2.9	4.2	9.0	4.8		
28	5.5	5.2	18 4	7.0		
29	4.6	3.7	6 0	7.0		
30	2.4	3.8	7.6	5 0		
31	2.6	4.3	9.4	7.0		
32	3.0	3.6	13.0	13 0		
33	2.1	2.7	8 6	4.0		
34	2.8	6.1	6.0	4.0		
35	2.2	3.9	8.2	10 0		
36	8.6	4 6	10.4	5.1		
37	2 4	2.5	6.2	5.0		
38	3.5	2.7	4.4	9.8		
39	5.0	3.8	10 0	4.2		
40	2.6	3.6	5.4	4.0		

[2] Two days later.

[3] Three days (trial 1 completed on third day and also the rest of the series).

PLATE III



HEART AND BOW—PUZZLE NO 4

Scale for A, smallest division = 80", *scale for B and C* smallest division = 2". *A*, times for trial 1 for 9 subjects, *B*, entire curve for *Mt*—25 trials; *C*, medians for successive groups of 5.

TABLE VIII—*Continued*

	Ts	*Tu*	*Ry*	*Rd*
41	2.3	2.8	4 2	5.3
42	2.0	2.6	5.2	2.8
43	1.8	3.8	5.2	3.2
44	3.1	2 5	4.6	3.2
45	2.0	3.6	10.0	4.6
46	2.8	3.1	5.6	3.2
47	3.0	2.3	5.0	3.2
48	1.7	4.6	3.8	5.2
49	1.9	2.8	3.4	5.0
50	1.8	2.3	3.8	2 6

puzzle to work at." Subject noticed, however, the way in which the puzzle came apart and was able to describe it. "*Hold the heart* in the right hand and the bow in the left. Move the loop of the heart through the end of the bow. Can't describe the other movements; the rest is chance. Think I will get it next time." The essential movement was caught here, and the curve breaks abruptly to a lower level at this point. Details of technique were worked out in trials 11 and 13. Trial 11: "It is easier to run the loop of the heart under the end of the bar. Had done this before but just realized its importance." Trial 13: "Noticed that when the bow is in a vertical position the bar on the upper side should be in a horizontal position. Pass the loop underneath, and with a sort of twist pass the end of the bar through the loop of the heart." Trial 14: "Went through as anticipated. Feel that I understand solving the puzzle."

Rd. Trial 1: The subject tried various things in trial 1 which did not reappear in the later trials. There was finally a locus analysis which in this case was anticipatory and resulted in success. "Then a conspicuous part of one section caught the eye, and from that time it seemed certain that it must have something to do with the solution. . . . The final solution had some element of chance, I do not know just how I did it." Trial 4: "The way out seemed more familiar. I could foresee the result of the movement" There is a rather decided drop in the curve at trial 12. *Rd* had been using a very roundabout method of orientation, but in this trial she struck upon a shortcut which she consciously adopted. "It is not necessary to slip the bow over the indentation. Hold the puzzle so that the square ends of the bow and bar are above the indentation. Pull the loop of the bar down. Then push the end of the bow up." Trial 39: "Took the heart with the left hand and seized the bow with the right at once." This variation in method was a short cut on an earlier method of orientation. The drops in the curve are closely associated with the explicit analyses mentioned.

Ry. After trial 1 the movements were limited to the neighborhood of the ends of the bow and bar, *i. e.*, the general locus of attack was defined although there were persistent errors within that locus. In trial 1 the movements at other parts of the puzzle were connected with the idea of (*a*) getting loop end and part of heart inside the bow, and (*b*) pushing the bow inside the loop of the heart. The success of trial 1 served, although accidental, to eliminate the movements connected with those views, but the errors about the new locus persisted long. In trials 2 and 3 the puzzle came apart without the subject's noticing it. In trial 4 the heart was all ready to withdraw for ten seconds before he withdrew it. In trial 5 the correct position was not utilized until its fifth appearance. In trial 7 the subject said, "I think I have it now." There was apparently here a rough analysis of the main features of solution and there is a decided drop in the curve at this point. This analysis, however, did not include the necessary discrimination of the correct method of attack from a very similar but incorrect one. This incorrect position was chanced upon in trial 16 as the subject was trying to hurry. He became "rattled" and all his old errors connected with the general locus of attack reappeared. These persisted in the immediately subsequent trials and high and irregularly fluctuating records result. The interval of two days between trials 21 and 22 comes 6 trials later than the beginning of this period and so can not be held responsible for the loss of speed, though it may have contributed to that result.

The period of mental confusion as to the main line of solution cleared up in trial 26. The subject showed, toward the end of this trial, signs of increasing alertness. He made the taking-off movement with decision; numerous similar opportunities in the same trial had been passed by. One error which appeared six times in this trial did not appear again in the series. He mentioned, however, at this point that he did not yet understand the error which precipitated the catastrophe in trial 16. This error was avoided during the later part of the series, but the reason for the error did not become clear to the subject until after the close of the series, when he was given the puzzle to examine for that purpose.

The errors, in the case of this subject, dropped out in the inverse order of their difficulty of discrimination from the essential movement, the false movements most like the correct movement dropping out last. Pushing the body of the heart instead of the reentrant loop dropped out first, trial 4. The further errors are all concerned with the pushing of the loop. Pushing the loop through the bar instead of the bow dropped out in trial 7. This is the easiest discrimination

as to the use of the loop. Pushing the loop through the bow end from the wrong side disappeared in trial 9. It was explicitly recognized as an error. Getting the loop crosswise of the bar after inserting it in the bow disappeared in trial 24; while putting the loop through the bar end after having put it properly through the bow end remained until trial 27. The last-mentioned error hung on, after it was recognized to be an error, as a result of the disaster in trial 16. The correct method seems to have been worked out to a sufficient degree to serve as a guide in the later trials although the error in question was not understood. This case illustrates how slow and gradual the development of discrimination may be.

Ta. The first success for *Ta* was purely accidental. He gained, however, a vivid picture of the final position as the puzzle came apart, and on the basis of this image the analysis of the essential movement took place at once. The subject attacked the puzzle in trial 3 with complete certainty as to the essential movement, and in trial 7 he was able to anticipate the details of manipulation. No important variations were introduced later in the curve. There is evidence of a final spurt. The curve of *Ta* may be contrasted with that of *Mt* as to the initial drop since the first success was in each case accidental and the times for the first success were approximately the same. The time for trial 2 for *Ta* is, however, only one twentieth that of *Mt*. As contrasted with the gradual dropping out of errors in the case of *Ry* there is complete disappearance of errors in the case of *Ta* after trial 1.

Tz. Trial 1: " . . . The puzzle was finally studied and as many possible combinations as occurred were followed either mentally or by actual doing, but the final solution was largely by accident as I did not expect that that trial would be successful." The long time of trial 2 is due to the fact that the subject made an explicit memory error as to the direction of the movement. This error was definitely recognized in trial 2 and did not reappear. "My recollection that I inserted the loop in the reverse direction in trial 1 was probably wrong as in trial 2 I was unsuccessful until I inserted it in a contrary direction, which makes me think that I must have inserted it in that direction for the first time, also the situation seemed familiar when success came."

In trials 3, 4 and 5, the attention of the subject was directed to the question whether any other mode of solution was possible. He convinced himself that there was none, and, beginning with trial 6, his attention shifted to the gaining of facility in manipulation. Important variations in method were consciously worked out in trials 8, 9, and 13, and there is a rapid and uniform decrease in times to a

very low limit in trial 24. Trial 8: "Tried a new way. . . . Thought that manipulation might be easier to take hold of the straight rod, as that is the one to be turned to release the ring. However, I experienced trouble with the bow." Trial 9: "Taking the bow in the left hand and manipulating the bar with the fore and middle fingers while removing the heart with the right hand-hold before the fore and middle fingers gives best results so far." Trial 13: "I think that a firmer hold of the bow would help the manipulation of the bar." The long time of trial 16 was the result of an accident. The subject made a quick move and barely missed getting the puzzle apart. He was greatly surprised to find it still together and became embarrassed and perplexed. He pulled himself together, however, and then solved as before. It is interesting to note that the disasters of *Ry* and *Tz* came on the same trial, number 16; that in the case of the latter recovery was immediate and complete, while in the former there was a prolonged relapse, and that there had been explicit analysis of method of manipulation in the case of *Tz*, but not in that of *Ry*.

In trial 25, *Tz* deliberately abandoned one of the methods of control worked out in trials 8 and 9, and adopted a less secure method which seemed to promise greater speed. The curve rises after this and the results are more irregular until the very end. This unfortunate change of method was suggested by a chance variation in trial 25.

It may be of interest in this connection that Tz was the oldest of the subjects concerned, and that he had had no special training in motor lines, that he considered himself to be clumsy, and yet that he made the lowest and best record with this puzzle, and that this greater success in manipulation was correlated with many effective variations of method and explicit consciousness in their employment.

(4) The accompanying table for the Triple Horseshoe puzzle includes six curves from subjects under normal conditions, marked *Bg, Co, Mc, St, Tz* and *Br;* one curve from a subject who worked with his hands behind his back and without seeing the puzzle, *Wh;* and two curves from subjects working under distraction, *Tr* and *Rs*. The distraction consisted in counting to two hundred by adding digits which constantly varied within the limits 2 to 9, of then reversing the process until, as a result of continued subtraction, negative 200 was reached, then of reversing again and passing through zero to plus 200, etc. The subjects counted aloud and were required to do all the work mentally. Since the digits ran up from 2 to 9 and down again, changing each time, and since there were changes at the limits also to be borne in mind, the task proved to be an ex-

acting one. An additional subject, *Ds*, working with distraction, failed to solve the puzzle although 2,700 seconds were spent upon it.

TABLE IX

THE TRIPLE HORSESHOE

	Bg	*Co*	*Mc*	*St*	*To*	*Br*	*Wh*[4]	*Th*[5]	*Rs*[6]
1	325.0	194.0	604.4	967.6	623.4	168.6	428.6	237.0	1,285 0
2	63.0	50.0	28.8	102.0	34.6	85.0	1,177.0	1,047.0	285 0
3	26.4	8.0	9.4	10.6	73.0	60.4	222.4	160.0	453.0
4	64.6	12.0	6.4	5.4	59.0	69.4	14.4	325.0	435.0
5	18.0	24.4	18.4	59.4	39.0	95 0	96.2	251.0	
6	12.0	10.0	10.6	9.0	26 0		64.0	448 0	
7	11.0	4.0	22.0	13.0	35.0		34.2	59 0[6]	
8	5.0	22.0	10.6	75.4	108.0		25.6	22.0	
9	4.4	5.0	14.4	93.0	61.0		31.0	23.0	
10	35.0	24 0	5.0	14 6	18.0		24.6	42.0	
11	12.0	6.0	4 2	56.6	10.4			83.0[7]	
12	8.6	2.0	5.6	9.2	10.0			7.0	
13	7.4	43.0	12.8	8 0	10.6			5.0	
14	3.4	34.0	5 0	12.0	91.7			4.0	
15	7.4	9.0	14.0	4.4	23.6			17.0	
16	6.6	9.0	5.4	12.4	60.8			17.0	
17	11.4	6.4	6.4	37.8	40.0				
18	7.4	8.0	8.8	16.2	33.4				
19	5.0	15.0	13 6	3.8	9.8				
20	6.8	13.8	5.6	12.4	21.0				
21	4.6	51.0	5.4	4.2	26 0				
22	4.6	2.0	16.6	7.0	19.6				
23	3.6	16 0	4.2	3.6	6.8				
24	2.8	8.6	4 4	22.2	7.6				
25	14.4	2.0	5.0	6.8	21.0				
26	16.0	13.0	3.8	6.6					
27	9.8	7.0	19.0	10.8					
28	3.4	3.6	9.0	6.0					
29	13.0	4 0	3.4	4.0					
30	15.0	3.0	13.6	6.4					
31	2.6	6.0	11.0	6.0					
32	13.0	14.0	4.4	2.6					
33	5.2	7.0	3.8	3.2					
34	7.0	7.0	10.8	21 4					
35	6.0	21.0	4.0	4.0					
36	17.0	21.0	4.4	4 6					
37	6.4	15.0	4 6	4.8					
38	5 0	5.0	3.2	3.0					
39	5 0	4.4	4.2	10.4					
40	3.4	3.8	8.6	28 2					

[4] Hands behind back, vision excluded, but no distraction.
[5] Distraction by counting.
[6] Following day.
[7] No distraction.

TABLE IX—*Continued*

	Bg	*Cs*	*Mc*	*Sl*
41	2.4	2.0	7.8	3 0
42	5 0	3.6	4.2	2.8
43	4.6	5.0	4.0	3.0
44	2 2	7.4	3.4	4.2
45	7 0	8 0	4 6	3.0
46	3.4	3.8	8.2	4.2
47	12.0	11.0	7.6	3.0
48	2 0	7.6	4.8	5.6
49	8 0	3.4	19.0	29 0
50	4.2	2.2	4.6	10 0

The puzzle is a very difficult one to control, and none of the subjects hit upon the precise twist required to give both speed and stability. This accounts for the unusual variability in the last part of the curves of the normal subjects.

Despite his handicap *Wh* managed to analyze out an important step in the process in trial 2, and to add to it in trial 4. He did not succeed, however, in mentally constructing the transformation so that he felt that he understood the puzzle geometrically.

The distraction in the case of *Rs* was very complete, and there was no further drop after trial 2. The result was similar in his case with the Twisted Nail puzzle where the series was much longer, 21 trials.

Tr's attention slipped in trial 6, as he felt success coming, from the counting to the puzzle and he analyzed the essential movement during that slip. There is a sharp break here to a lower level. Distraction was discontinued in the eleventh trial and there is another drop in level at this point. The experiments with distraction were performed to determine if repeated success plus the emotional accompaniment would stamp in the habit if attention were left out. So far as it goes the evidence is negative.

(5) See Table X and Plate IV.

The curves *A* and *B* are similar in that the solutions were in each case the result of a thoroughgoing anticipatory analysis resulting in a sudden sharp drop to a very low level. The curves are also similar in the uniformity attained in manipulation times. The physical conditions of the puzzles were more favorable for accurate manipulation than in the case of most of the puzzles.

Puzzle *A* was solved by systematic exhaustion of possibilities by means of successive dilemmas. 1,296 different combinations were possible and solution by any other method appears highly improbable. The drop in trials 3–5 was connected with the conscious adoption of shortcuts and the substitution of memory cues for fresh analyses. The drop at trial 12 was connected with the conscious

TABLE X

	Tr A	Wk B	Tr C	Tr D			Wk D	Wk E	Tr E
1	13,500 0	2,000.0	18,000.0	1,037	75*	35	5,320	—	547
2	1,295 0	350.0	178.0	505	40	26	240	62	71
3	280 0	39.0	152 0	340	80	29	185	27	90
4	80 0	26 0	134.0	185	47	22	215	25	40
5	30.0	20.0	118.0	333	91	24	200	21	106
6	33.0	21.0	73.0	162	75	28	120	22	48
7	25.0	20.0	72 0	155	58	30	95	22	108
8	20 0	18.0	67.0	98	104	28	78	18	255
9	18.0	18.0	66.0	103	69*	23		22	37
10	60.0	17.0	41.0	60	57	30		21	22
11	21.5	19.0	66.0	100*	97	24		18	22
12	22.0	17.0	77.0*	81	69	23		24	40
13	19.0	19.0	145.0	64	56	25		20	22
14	18 0	16.0	80.0	70	69	24		16	18
15	31.5	12.0	114 0	75	67	20		19	15
16	20.0	13.0	97.0	59	56	21		16	13
17	15.0	15.0	77.0	127	40	22		16	15
18	19 5	18 0	94.0	99	52	29		16	15
19	17.5	13.0	112.0	58	47	23		17	15
20	16 5	13.0	63.0	64	49	20		15	14
21	21.0	21.0	80.0	60	61	26		15*	14
22	18.5	17.0	85.0	55	45	24		18	13
23	16.5	25.0	65.0	55	78	20		15	13
24	17.5	17.0	50 0	74	41	24		16	13
25	17.0	18.0	87.0	65	40	22		17	11
26	13.5	13.0	105.0	65	47	20			
27	13 0	36 0	76.0	62	36	18			
28	12.0	19.0	56 0	46	32	24			
29	12.0	19.0	62.0	57	29	28			
30	12.5	15.0	54.0	48	58	30			
31	16.5	14.0	39.0	58	36	25			
32	16.5	17.0	53.0	68	27	19			
33	12.0	14.0	146.0	43	28	17			
34	31.0	13.0	95 0	46	34	17			
35	14.0	15.0	57.0	48	25	18			
36	9.5		45.0	58	27	35			
37	14.5		102.0	51	35	21			
38	15.0		50 0	50	37	21			
39	12 0		65.0	99*	30	21			
40	12.5		69 0	67	22	20			

A, Katzenjammer Puzzle.
B, Jig saw, Ivory, Square.
C, Wizard Cross.
D, 12-piece Cross.
E, Lone Star War.

C, trial 12*, = 3 days later.
D, trial 11 , = 10 hours later.
D, trial 39 , = 1 hour later.
D, trial 51 , = 5 hours later.
D, trial 59 , = 3 hours later.
D, trial 97 , = 12 hours later.

TABLE X—*Continued*

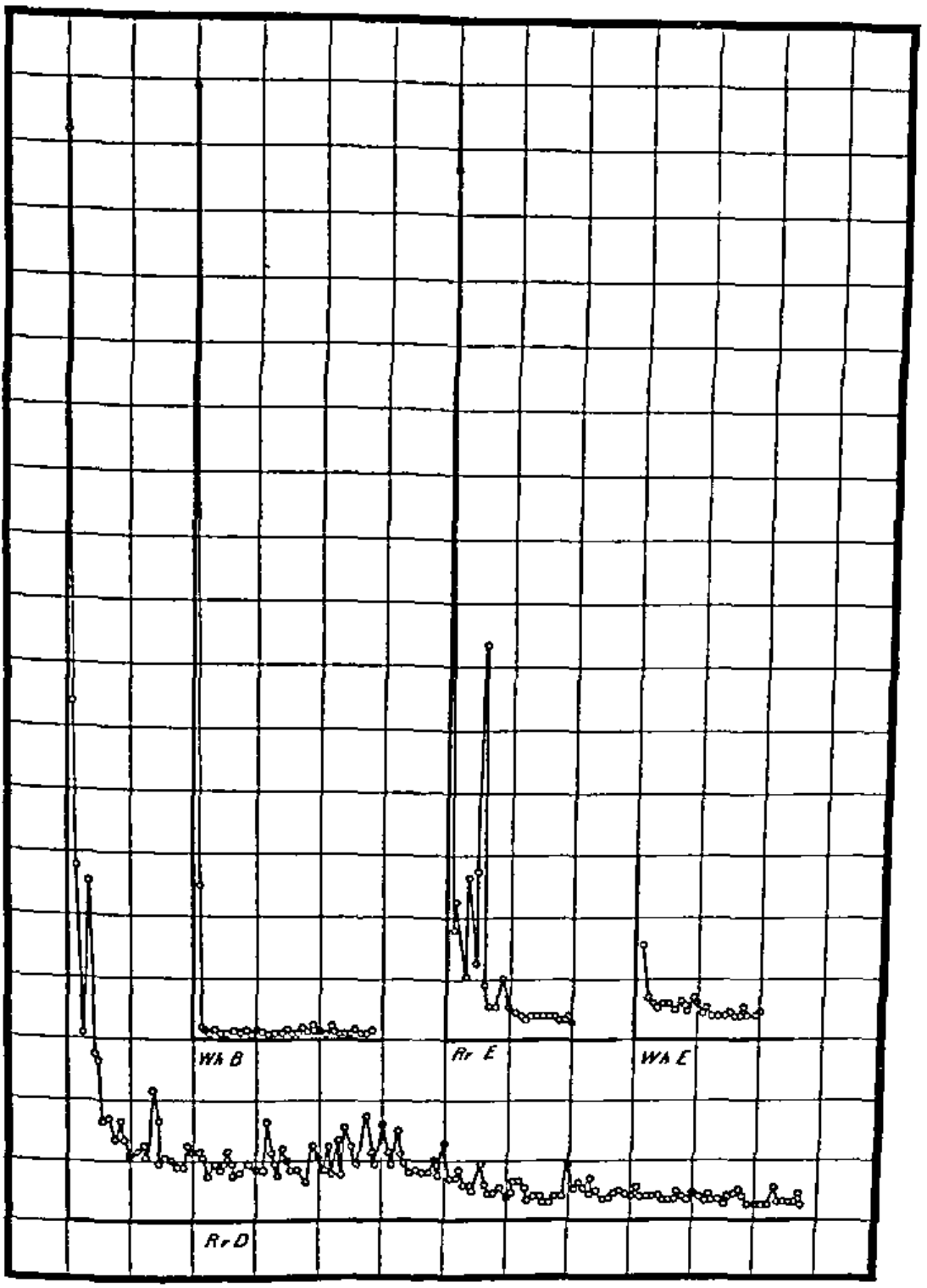
	Er A	Er C	Er D		
41	12.0	65.0	56	23	28
42	12.5	53.0	43	23	10
43	12.0	51.0	71	22	
44	11.5	50.0	59	22	
45	11.5	47.0	50	24	
46	12.0	55 0	61	24	
47	11.5	53.0	40	56*	
48	12.0	41.0	75	30	
49	10.5	41.0	62	32	
50	10.5	40 0	51	30	
51		36 0			
52		48.0			
53		36.0			
54		33.0			
55		159.0			
56		53.0			

substitution of a new order, an order of convenience in place of the order of discovery. The substitution was the result of a perceptual impulse which was immediately approved in judgment. The inertia of the mentally established made itself felt however in a dread of change as such. But the change was made and it proved to be of value.

The drop at trial 25 was connected with a consciously adopted variation. "Used the heart-diamond-club as check with the green." The drop in trial 38ff. was connected with the adoption of the verbal cue "spade-two diamonds" before trying the purple, and with "a negative recognition of the orange."

No instructions were given to *Wh* as to the sort of figure to be constructed from the ivory pieces of puzzle *B*. The cross seemed probable and in testing that hypothesis the square was suggested. This was then chosen as *the* hypothesis because it could be exhaustively tested. The square on the hypothenuse side of a large rectangle was selected after a table of the squares on each of the sides had been compared with the approximate total area of all the pieces. The square was then constructed. Quotation from *Wh*'s account for trial 2 will show the ready supplanting of analysis by memory, and the volitional character, the stubbornness, of the memory assumption. "I put the two large triangles together at once and remembered which pieces went together to form the third side, but got these two in the wrong order, and fussed around with all sorts of combinations without thinking of changing the order of these two pieces. I think the reason I got the wrong order was that in the first round when I

PLATE IV



Scale of *Rr* D. smallest *division* = 6", scale of Wh B smallest division = 14"; scale of *Rr* E· smallest division = 4"; scale of Wh E smallest division = 4".

noticed that these two pieces would make up a side, I began with the triangle and looked for something to make up the proper length, and found the parallelogram suitable. So, I had the order: triangle—parallelogram in mind; but this was the order of discovery, not the order of arrangement on the square. What finally deflected me from this false order was partly the inability to get the other pieces together, and partly, perhaps, a recollection of the fact that had impressed me when I looked at the completed square after my first success, namely, that there was a triangle in one corner. This came back to me once or twice, I think, while I was working over the pieces, and I believe it came up just before I altered the order of the pieces."

Trial 3: "Got the pieces which troubled me last time correct without hesitation. The rest of the time was principally occupied in getting the positions exact enough to give a good square."

Trial 4: "Knowledge of the exact positions of the last three pieces to be inserted saved some little time."

Trial 8: "Time saved by getting the pieces near together and squeezing them at the close."

Trial 10: "Carried a little further the device mentioned in 8."

(In trial 20 the subject changed the position of the first pieces and this was followed by more irregular and longer times.)

C. The Wizard Cross is composed of six square-cut wooden bars notched in the centers so as to interlock and form a tridimensional cross. There are a great many notches in each bar and the number of possible combinations is very large. The actual solution by *Rr* seemed to have involved three principal factors: (1) Practise in the discrimination of the parts, (2) selection of combinations in accordance with the requirements of the complete cross (as mentally pictured), (3) an attempt to exhaust the possibilities thus limited by beginning with each different type of piece—there were two pairs and two odd pieces—and working the limited combinations systematically. The solution came during this systematic search. The chief points in the practise with this puzzle were concerned with the perfecting of the discrimination of the different bars with anticipatory adjustment, and the simultaneous use of all the fingers. The notches were different on the different faces of the same bar, and it took considerable practise to hold the distinctions in mind so that a given bar could be recognized from any face. This was not perfectly accomplished during the series. There was considerable growth in anticipatory adjustment, but there was no such final unity as with the Chinese Ring. This difficulty was both simultaneous and successive. The pieces did not lock well until the last was in, and the

task of holding three or four or five pieces from slipping while inserting another and preparing for the next step was not an easy one. There were numerous slips even to the end. The puzzle, then, is much more difficult of manipulation than *A* or *B*, and, although many control variations were followed up, a thoroughly satisfactory one had not been hit upon by the close of the series.

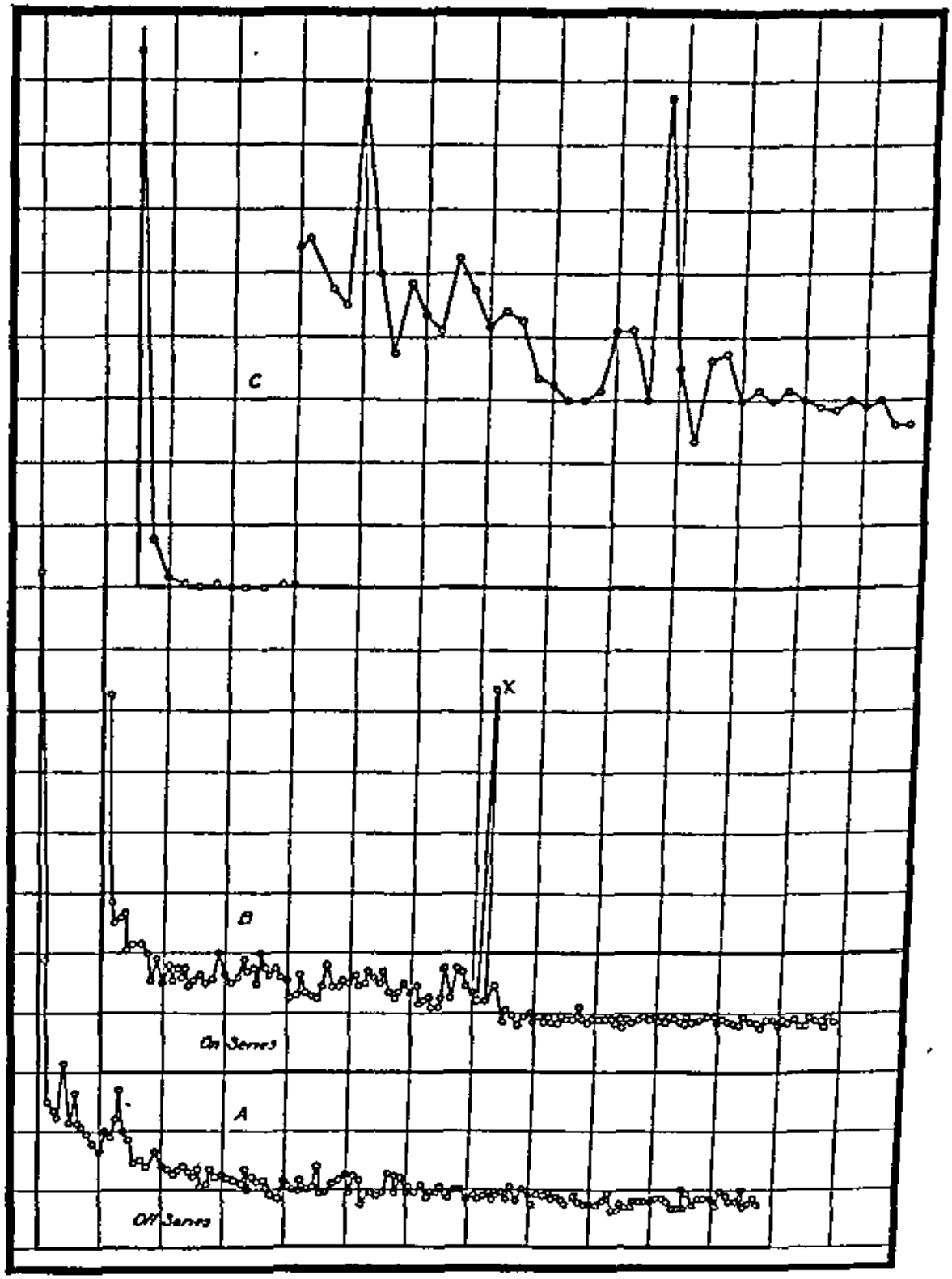
D. The Twelve Piece Cross was similar to the Wizard but the notches were simpler. There were, however, twice as many parts. *Er* solved the puzzle 142 times and the table shows that the time of manipulation was very much reduced and that the puzzle was gotten under good control. This was in spite of the fact that the puzzle was so complex in manipulation that no sooner would one point of manipulation seem fairly well settled than a new difficulty would break out requiring readjustment all around or switching the attention off the method previously concerned. Contrary to the usual custom the analysis was not restricted here to the snap-shot type, but ten minutes was taken at trial 81 to work out a new technique. There is a decided drop in the curve in this locality and a great decrease in variability.

The significance of consciously employed variations is illustrated again by the drop in *Wh*'s curve in trial 7. To quote—Trial 5: "There is some difficulty in getting one of the pieces." Trial 6: "Trouble at the same point as before. . . . The difficulty can be avoided by raising one of the pieces and so easing the whole joint." Trial 7: "Time mostly saved by the device mentioned in the last entry."

E. Wh tried to get the puzzle, the Lone Star War, at first by random manipulation, but failing there he resorted to analysis. He employed a method which he transferred from mathematics and often attempted to use with the puzzles, namely, to consider the puzzle solved and then to retrace the steps. The method was successful here. The method was made more explicit and unified by an additional bit of analysis in trial 2. *Wh* then turned his attention to the problem of telescoping. "The overlapping is helped, perhaps, by using the hands not absolutely simultaneously on symmetrical wholes, but alternately, thus getting ready for the next pair while inserting the second of the preceding pair."

Wh tried on his own initiative the experiment of putting the flags in the holes in any order instead of the fixed order required to solve the puzzle. The last five records are of this attempt, and their average is 16.2 as against 16.0 of the five in the fixed order just preceding. The prescribed order is as easy or easier than the random.

PLATE V



A AND *B*, STAR AND CRESCENT PUZZLE, No. 11

By averages of tens. Scale: smallest division = 0.8". *B*, analysis at *x*.

C, KATZENJAMMER PUZZLE, No. 35

Rr subject. Scale: trials 1–11 smallest division = 160"; scale: trials 11–50 smallest division = 0.4".

Rr solved the puzzle by chance manipulation the first time. He then tried to rely on memory, but in trial 8 he gave up this unsatisfactory method for one of analysis. The analysis was not however of so deductive a type as *Wh*'s. Trial 8: "Took time to work out a scheme: Place one of the flags opposite Havana at Malanzar, four next to Havana, then the two points, and then the two angles. This scheme was recognized geometrically—names not noticed, order of the four not yet memorized." Trial 13: "The order is: four corners, then center." The four had been giving trouble in trials 9–12. Trial 14: "Correct: memory and perception; conscious telescoping."

(6) The accompanying diagram gives the curve for *Rr* for 1,440 solutions of the Star and Crescent puzzle.

CHAPTER VI

TRANSFER

1. RESULTS IN DETAIL

(1) *Wh* and *Re* were subjects in a series of experiments with the Jiu Jitsu puzzle, all but one of the experiments being tried with *Wh* only. This is a small puzzle consisting of two symmetrical parts which are to be separated. Each of the parts resembles a small staple, the arms of which have been bent back at their middles 180 degrees, the points of the arms being brought so close together that the points of one of the staples if held at an angle of 90 degrees would barely pass through those of the other. If this has been done and the staples pushed clear in so that they touch at the necks, then the puzzle is in the usual position for solution, which consists in the reverse process of removing the parts. If one of the staples be held in a constant position, the other may be pushed on it from either the right or the left. The initial movements in taking off are different for these two cases, but the discrimination is not an easy one to make. For each of the right and left methods of insertion two positions of the puzzle were chosen. These positions were such as would result if the puzzle were held vertically and freely. They differed merely in that one was obtained from the other by rotating the puzzle 180 degrees. There were thus four principal positions. These were: A, right insertion, zero degrees; B, right insertion, 180 degrees; C, left insertion, zero degrees; D, left insertion, 180 degrees. The positions are referred to in the following discussion by the letters A, B and C, D, just given. The positions of a given pair, A and B, or C and D are more closely related than positions from separate pairs.

(a) There was decided transfer between the processes of taking the puzzle apart and putting it together. The subject practised 400 times taking it apart without being allowed to put it together or to see it put together. He was then given five trials at putting it together. The average time in seconds for the first five trials in taking the puzzle apart was 46, while in putting it together it was only 4.6, one tenth of the former; the longest record of the latter series was 7 seconds and the average deviation was 0.9. The transfer here was evidently one of method or idea, as the motor habits built up in the

former, analytic, series would be the reverse of the ones in the latter, the synthetic.

(*b*) There was transfer from the C position to the D. This does not appear strikingly if only the first trial of each series be compared, but it comes out clearly if the immediately following ones are examined. The first trial for C took 18.4 seconds, of D 9.6 seconds, but the average of the immediately succeeding five trials is 17 seconds for C and only 1.9 for D. Since the times for the second ten trials with C average 1.8 and with D 1.6, the drop in times of D can not be attributed to greater ease of manipulation. The subject's record for trial 143, No. 1 of D: "Found that by turning the thing a quarter toward me, it would be in the position of the last few trials. Turned it and used motor habit number 2." The transfer here, then, depended on the analysis which enabled the subject to employ his motor habits.

(*c*) The subject was given a special practise series, with the A position, of 40 trials, the average of the first five being 7.3 and of the last five, 1.4. He also practised with eyes closed and hands placed in position, the average for the last five trials being 0.36 second. The subject was next given 90 trials with the three other positions, and was then told that he would be tried again with the A position. The average of these five trials was 15.8 seconds, twice as long as that of the first five of the special A series and eleven times as long as that of the last five of that series. The interference here seems to have been that of the C and D positions just practised, and to have been due to a failure to control the habits by a carefully discriminated idea of the relations of the different positions. This is borne out by the subject's record. During the fifth trial of this A test series, trial 167 in the table, he made the following analysis: "I was wrong. The right hand does not take the easiest hold, but the thumb is under . . . in positions A and B grasping the side more towards me or more anticlockwise, if the left hand is imagined to be farther away. In positions C and D the reverse must be the case . . . (trial 168). My scheme worked all right." Five more A's were then given. The following times are for the fives before and after the analysis; the second five begins with trial 169: trials 163–7, 25, 23, 13, 7, and 11 seconds; trials 168–172, 1.6, 1.4, 2.0, 2 6, and 1.4 seconds. This sudden change is evidently not in motor habits but in their control by an idea. The motor habit for A must have been carried nearly to perfection during the last part of the original series, for with eyes closed the average time for the last five trials was 0.36 second, practically one third of a second.

(*d*) In the following part of the experiment both subjects were

employed. *Re* practised during the whole series of 250 trials with the puzzle in a chance position. The operator varied the position of the two parts in putting the puzzle together in the two principal ways, right and left, mentioned above, and the sequence was irregular although the total number for each type was approximately the same. The puzzle was each time tossed in the air by the operator and so came down on the table in a chance position.

Wh practised 400 times with the puzzle in the four main positions, A, B, C, D, described above. He practised each of these four positions until he had developed a special technique for handling it in minimum time. He also practised solving the puzzle in minimum time with the positions taken in pairs, the members within the pairs coming irregularly, and with the four positions in chance order. The tactual motor coordinations were especially developed by a long series with the eyes closed. In the early part of these series, trials 29–32, the puzzle was tossed up in the air, the conditions being the same for these four trials as they were for all the trials in the case of *Re*. At the close of the series of 400 trials of *Wh* the puzzle was again tossed in the air, giving the chance positions as in the first test of four trials. The average time of *Wh* in the final test series, *28 trials, was 11.6 seconds, the average for the last ten was 9.1* seconds. The average of the four trials in the first test series was 12.2 seconds. The average time of the last four of the A, B, C, D positions, chance sequence, just preceding the second test series was 1.8 seconds. There was evidently, then, but little gain, in the handling of the chance positions in which the puzzle was thrown in the air, from all the special practise which had intervened. This conclusion is confirmed by comparison with the series of *Re*. The average of the first ten of his series of 250, all being tossed up, was 335 seconds, of the four trials, 29–32, corresponding to *Wh's* first test series was 41 seconds, and of the last ten, trials 240–249, was 7.2 seconds, the average of the last 28 trials, 222–249, being slightly lower, 7.0 seconds, and the average for his last hundred trials being 7.6 seconds. *Re's* results at the close of the series are considerably lower than *Wh's*, although the latter manipulated the puzzle 179 trials more than the former.

The practise on the chance positions directly seems, then, to have been much more effective for the handling of the chance positions than the reduction to fixed rules and mechanization of four principal positions. *If Wh's attention had been directed toward the developing of a general rule instead of four special ones, it is probable that* the transfer would have been greater.

TABLE XI

JIU JITSU PUZZLE. WA SUBJECT

The four main positions are designated A, B, C, D. A means right insertion and zero degrees; B, right and 180 degree; C, left and zero; D, left and 180.

1	53.4	44	4.4	A	86	2.0	B	128	0.8	C	173.	3.0	B
2	66.4	45	4 0	A	87	1.0	B	129	2.4	C	174	2.6	B
3	91.8	46	3.4	A	88	1.8	B	130	0.8	C	175	2 0	B
4	30.0	47	2.2	A	89	1.8	B	131	6.0	C	176	3.0	B
5	16.8	48	2.2	A	90	1.4	B	132	0.6	C	177	1.8	B
6	26.0	49	1.6	A	91	1.6	B	133	0.4	C	178	2.4	B
7	75.8	50	1.6	A	92	1.6	A	134	0.4	C	179	1.8	B
8	14.4	51	1.4	A	93	1.2	A	135	0.5	C	180	1.8	B
9	17.0	52	2.2	A	94	1.2	A	136	4.8	C	181	12.0	B[1]
10	8.0	53	1.2	A	95	0.6	A	137	1.6	C	182	5.0	A
11	8.0	54	1.0	A	96	1.8	A	138	1.0	C	183	2.4	A
12	7.4	55	1.0	A	97	1.2	A	139	0.8	C	184	3.4	B
13	39.2	56	1.4	A	98	1.4	B	140	2.0	C	185	8.4	C
14	15.0	57	1.2	A	99	2.2	B	141	1 6	C	186	12.6	D
15	8.0	58	1.6	A	100	2.6	A	142	9.6	D	187	10.4	B
16	5.0	59	1.4	A	101	1.6	A	143	2.2	D	188	30.0	D
17	5.0	60	1.4	A	102	2.8	B	144	1.4	D	189	14.0	C
18	8.0	Eyes closed,			103	1.8	A	145	2.8	D	190	60.0	A
19	10.6	hands in			104	2.0	B	146	1.8	D	191	19.2	D
20	5.0	position.			105	1.0	A	147	1.4	D	192	8.6	B
21	13.0	61	1.6	A	106	2.4	B	148	1.6	D	193	11.2	C
22	3.2	62	2.0	A	107	18.4	C	149	2.2	D	194	11.0	A
23	3.0	63	1.0	A	108	5.6	C	150	2.0	D	195	5.6	D
24	3.0	64	0.6	A	109	41.6	C	151	2.0	D	196	3.4	B
25	5.0	65	0.4	A	110	8 4	C	152	1.0	D	197	5.0	C
26	14.4	66	0.4	A	111	20.1	C	153	1.4	D	198	3.4	A
27	9.0	67	0.4	A	112	8.0	C	154	1.2	C	199	62.4	D
28	10.0	68	0.2	A	113	20.6	C	155	1.0	C	200	7.0	C
First test,		69	0.4	A	114	9.8	C	156	1.0	D	201	6.2	D
tossed.		70	1.2	A	115	3.6	C	157	2.6	C	202	4.6	C
29	20 0	71	4.0	B	116	4.0	C	158	1.6	D	203	21.4	B
30	7.4	72	3.4	B	117	2.6	C	159	1.6	D	204	10.6	D
31	7.4	73	2.8	B	118	1.6	C	160	2.6	C	205	7.2	A
32	15.0	74	2.4	B	119	1.6	C	161	1.6	D	206	5 6	C
33	3.2 A	75	1.6	B	120	1.2	C	162	1.6	C	207	4.4	A
34	7.0 A	76	2.8	B	121	1.4	C	163	24 8	A	208	7.0	D
35	4.6 A	77	1.2	B	122	2.8	C	164	23.4	A	209	4.4	B
36	15.8 A	78	1.0	B	123	1.4	C	165	13.4	A	210	5 8	C
37	5.4 A	79	1.0	B	124	1.4	C	166	6.6	A	211	7.2	A
38	8.8 A	80	2.6	B	125	2 0	C	167	11.2	A	212	3.6	D
39	6.0 A	81	1.8	B	126	1.8	C	168	1.6	A	213	5.6	B
40	4.4 A	82	2.8	B	Eyes closed,			169	1.4	A	214	5.4	C
41	23.4 A	83	3.0	B	hands in			170	2.9	A	215	6 4	A
42	3.6 A	84	120 0	B	position.			171	2 6	A	216	6.4	B
43	5.4 A	85	3.2	B	127	0.5	C	172	1.4	A	217	6.0	D

[1] Change of instructions: "Either A, B, C or D."

TABLE XI—*Continued*

Jiu Jitsu Puzzle. Wa Subject

The four main positions are designated A, B, C, D. A means right insertion and zero degrees; B, right and 180 degree; C, left and zero; D, left and 180.

218	5.0 A	262	2.2 C	303	7.4 B	345	3.0 B	389	2.4 B
219	6.4 C	263	2.1 B	304	4.4 A	346	3.0 C	390	2.4 D
220	12.0 B	264	2.5 D	305	4.4 D	347	2.4 A	391	2.5 C
221	8.6 D	265	2.8 D	306	5.0 C	348	2.2 D	392	2.4 B
222	4.6 A	266	2.8 A	307	4.0 D	349	1.8 B	393	1.8 A
223	4 2 A	267	3.4 C	308	2.4 A	350	2.5 C	394	2.2 D
224	3.4 B	268	2.8 A	309	5.0 B	351	4.4 A	395	1.5 A
225	7.6 D	269	3.4 B	310	3 4 C	352	2.2 D	396	1.6 B
226	5.6 C	270	2.2 C	311	4.0 B	353	1.8 D	397	2.0 C
227	5.4 A	271	2.4 D	312	3.0 C	354	2.8 B	398	3.4 B
228	7.6 B	272	2.0 A	313	3.8 A	355	4 6 A	399	1.4 A
229	5.4 C	273	2.2 A	314	4.2 D	356	2.6 C	Trials 400–404, puzzle put together. Second test, tossed.	
230	3.8 A	274	2.4 C	315	3 8 D	357	4.6 B		
231	4.0 B	275	3.8 B	316	3 0 C	358	2.4 A		
232	2.6 B	276	3.0 D	317	2.8 B	359	2.6 D		
233	7.0 C	277	3.6 B	318	4.0 A	360	2.6 C		
234	3.2 D	278	2.4 B	319	5.0 A	361	2.6 A	405	13.2
235	2.6 A	279	2.6 C	320	5.8 C	362	2.4 B	406	3.8
236	3.8 B	280	2.6 A	321	3.8 B	363	20.0 D	407	6.0
237	2.8 D	281	3.6 D	322	2.8 D	364	2.2 C	408	12.0
238	3.2 C	282	2.6 A	323	4 0 C	365	3.4 B	409	7.0
239	3.8 A	283	2.6 C	324	7.2 B	366	2.8 A	410	12.0
240	3.8 B	284	4.8 D	325	3.2 A	367	2.2 D	411	4.2
241	2.6 D	285	2.2 D	326	3 6 D	368	3.8 C	412	11 4
242	2.2 A	286	2 2 A	327	5.0 C	369	2.2 A	413	9.0
243	2.4 C	287	1.8 C	328	3 0 B	370	2.6 B	414	19.0
244	2.4 B	288	2 0 B	329	2.6 A	371	4.6 D	415	19.4
245	3 0 A	289	3.8 C	330	5.0 C	372	2 6 C	416	7.2
246	2.4 D	290	3 0 B	331	3 2 A	373	4.9 D	417	35 6
247	3.4 C	291	2.2 A	332	5.8 B	374	2.4 B	418	8.2
248	2.6 B	292	3.4 D	333	3.0 D	375	2.2 A	419	6 0
.....[1]		293	2.2 B	334	3.4 C	376	2.8 C	420	27.6
249	4.6 C	294	2.6 C	335	2.4 A	377	3.0 B	421	21.6
250	2.8 B	295	2 0 B	336	3 8 B	378	2.4 D	422	7.4
251	2.8 A	296	1.8 A	.. ..[2]		379	2.6 B	423	3 0
252	12 2 D	297	2 0 C	Eyes closed, fingers near.		380	2.4 C	424	3.8
253	2 6 B	298	2.4 B			381	2.4 A	425	19.2
254	2 5 A	299	2.4 D	337	5.8 C	382	1.8 D	426	8.4
255	2.4 C	300	2.0 A	338	5.8 D	383	1.8 B	427	5 0
256	3.0 A	301	2.4 B	339	6 6 B	384	2 0 D	428	11.4
257	2.5 D	302	2 4 C	340	4.8 A	385	2.4 A	429	15.6
258	3.2 B	Eyes closed, fingers near, not in position.		341	2.4 D	386	2.0 C	430	14.4
259	3.6 C			342	2.4 A	387	2 0 B	431	4.2
260	2 6 D			343	4.6 C	388	3.4 C	432	6.0
261	2 4 B			344	2.8 B				

[1] One day later.

[2] Eight-hour interval.

The subject worked with eyes open except in the cases specially designated, 61–69, 127–141, 337–399.

The times for putting the puzzle together are as follows: 400, 7.0; 401, 3.8; 402, 3.8; 403, 3.8; 404, 5.0.

TABLE XII

Jiu Jitsu Puzzle. *Re* Subject

Puzzle put together right (R) or left (L) and then tossed up in the air to fall by chance.

1	415.0	51	35.6 L	101	10 8 R	151	6.4 L.	201	6.8 R
2	98.4	52	23 6 L	102	53.0 L	152	10.6 L	202	4.0 L
3	749.0 L	53	5.4 L	103	9.0 R	153	8.8 R	203	6 0 R
4	600 0 L	54	10.4 R	104	17.4 L	154	17.4 L	204	16 6 L
5	110 0 L	55	3.4 R	105	43.0 L	155	7.6 R	205	7.4 R
6	203 0 R	56	12.0 L	106	7.6 R	156	12.0 L	206	10.0 L
7	108 0 R	57	27.0 R	107	18.4 L	157	4.4 R	207	8.8 R
8	642.0 R	58	9.4 R	108	3.6 R	158	2.6 R	208	3.4 R
9	263.0 L	59	7.4 L	109	6.4 L	159	9.4 L	209	32.0 L
10	162 0 R	60	5.6	110	4.6 R	160	12.0 R	210	5 2 L
11	63 0 R	61	5.0	111	15 0 L	161	7.0 L	211	2 0 R
12	118.0 L	62	2.8	112	9 6 L	162	4.4 R	212	6.4 L
13	23 0 R	63	64.0 L	113	3 6 L	163	4.0 R	213	3.2 R
14	37.0 R	64	14.6 L	114	14.0 R	164	13.4 L	214	9.0 R
15	568 0 L	65	7.4 R	115	24 0 L	165	3.2 L	215	5 4 L
16	62 0 L	66	8 6 L	116	25.0 L	166	8.8 R	216	9.2 L
17	46 0 L	67	12.4	117	20.0 R	167	5.2 R	217	8 6 L
18	91.0 R	68	7.6	118	13 0 R	168	10.6 L	218	14.6 L
19	75.0 R	69	4.4	119	8.6 L	169	8.0 L	219	3.0 R
20	505.0 L	70	9.0 L	120	12.0 L	170	4.4 R	220	11.8 L
21	49.0 L	71	26 6 L	121	6 0 R	171	5.6 L	221	4 8 R
22	133.0 L	72	4.4 L	122	8.4 R	172	2.6 R	222	5 2 R
23	16.0 R	73	41.4 R	123	7.6 L	173	10 8 L	223	10.4 L
24	154 0 L	74	5 0 R	124	30.4 L	174	15 4 L	224	1.4 R
25	98.0 R	75	10.2 L	125	2.0 R	175	6.0 R	225	6 4 L
26	16.0 R	76	10 6 L	126	11.0 R	176	6.4 L	226	6.4 R
27	15.0 R	77	7.4 L	127	16.8 L	177	6.8 R	227	8 2 L
28	130.0 L	78	12.6 R	128	3 0 R	178	5.8 L	228	12 2 L
29	53 0 R	79	7.2 R	129	8.6 R	179	5.4 R	229	6 6 R
30	50 0 L	80	8.8 L	130	14 0 R	180	7 4 R	230	7.0 L
31	11.0 L	81	7.2 R	131	43.0 L	181	15.0 L	231	2.4 R
32	50.0 L	82	4 4 L	132	8.8 L	182	8 2 R	232	6 4 L
33	51.0 L	83	16.4 L	133	6.2 R	183	5.8 L	233	9 0 R
34	8 4 R	84	56.0 L	134	8.8 L	184	8.8 R	234	13 4 L
35	77.0 L	85	10.0 L	135	6.0 R	185	3 0 R	235	8 2 R
36	12.6 R	86	8.6 L	136	6 6 R	186	6 6 L	236	6 2 L
37	31 0 L	87	41.6 L	137	17 0 L	187	12 4 L	237	4 0 R
38	29.0 L	88	7.0 L	138	13.6	188	3 2 R	238	7 0 L
39	24 0 R	89	15 0 R	139	2 3	189	7 4 L	239	3 6 R
40	68 0 L	90	11 0 R	140	14.0 R	190	4 0 L	240	11 0 R
41	34 0 R	91	7.0 R	141	9 6 R	191	4.8 R	241	5 4 L
42	13.0 L	92	11.4 L	142	19.0 R	192	7.4 R	242	3.0 R
43	16 0 R	93	5 6 R	143	6.8 L	193	2.4 L	243	13 8 R
44	68 0 L	94	45.4 R	144	1.6 R	194	13 0 R	244	7.8 L
45	16 0 L	95	16.4 L	145	7.4 L	195	8 4 L	245	4 6 L
46	32 0 R	96	6.4 L	146	3.0 R	196	5.8 L	246	5 4 R
47	34 0 R	97	7.0 R	147	30 0 L	197	5.4 R,	247	5 2 L
48	10.4 L	98	8.4 L	148	6 6 L	198	11.4 L	248	11.6 R
49	6.6 R	99	8.2 R	149	8.2 L	199	4.0 R	249	4 2 L
50	4.0 R	100	9.4 R*	150	8.4 R	200	10.6 L		

* 24 hour interval.

(2) *Rr*, acting as both subject and operator, solved the Double-hinged Dart and Ring puzzle seventeen times before noting explicitly that there was a right and left form solution. This analysis was made explicit during the eighteenth trial; the difference had been vaguely felt previously, and the explicit analysis seems to have been aided by the similar analysis previously made for the Jiu Jitsu puzzle. In the next three trials the subject tested his ability with the right-hand method, the A position. He then practised 139 times with the left or B position, and then took a test and practise series with the A position, trials 161 to 200. As *Rr* was both subject and operator this series is different from the others in that it includes the times for putting together, given in separate columns, as well as that of taking apart. The times of the three A trials of the first test were 22, 21 and 20 seconds, average 21 seconds; if the time for the trial just preceding, in which the difference between the A and B positions was worked out, be included, the average of the four A's amounts to 27 seconds. The average of the first twenty of the second A series was 71.7 seconds, the average of the first three being 93 seconds. The average of the first twenty of the B series was 53 seconds and of the last twenty was 10.1 seconds. The B process was thus highly perfected, but the times for the second A test are from three to four times as high as those of the first test. The transformations required in the case of this puzzle are very complex, although the general plan of solution is simple. The detailed moves in the B solution were analyzed out very well, but the whole series of movements involved were not worked up into a single unified mental construction. Consequently the subject was not able to construct a solution for the A position on the basis of the one for B. This might have been done, since the processes are symmetrically related, if the construction had been made for B. In consequence of this failure there was no idea to control the motor habits, and there was decided conflict, or "negative" transfer, as the result of the training with the B series.

(3) *Wh* was tested with three trials with a puzzle constructed by interlacing two "Gem" paper fasteners. He was then given a practise series of 109 trials and then again tested with the initial position. The practise series was so arranged that by means of part movements arranged from simple to complex there was direct training for the manipulation required in the second test. All that was needed for rapid manipulation in the second was that the second test position be seen to involve but a single slight initial movement in addition to those used with the member of the practise series just preceding. When the second test series was given, the position was not, however,

TABLE XIII

DOUBLE-HINGED DART AND RING. *Rr* SUBJECT

	Off	On	Off	On	Off	On	Off	On
1	80.0	72.0	23.0	8 5	10.5	7.5	12.5	6.5
2	70 0	72.0	10 0	4 0	13.5	5.0	11.0	5 0
3	35.0	40.0	40.0	4 0	26.0	12 5	10.0	5.0
4	47.0	21.0	13 0	6.0	10.0	8.5	9.0	26 0
5	27.0	18 0	37.0	5.5	14 0	7.5	8.0	6 0
6	72.0	18.0	40 0	21 0	10 0	10 0	8.5	6 5
7	180 0	26.0	50.0	7.5	20.0	8.5	8.0	5.0
8	21.0	26 0	41.0	4.5	12.5	4.5	11.5	6.5
9	65.0	17.0	16.0	5.5	30 0	5.0	8 0	7.5
10	60.0	25.0	13.0	7.5	10 0	4.5	8.0	4 5
11	70.0	13.0	13.0	11.0	120.0	5.5	47.0	5 0[b]
12	32.0	33.0	28.0	7.0	15 5	6 0	165.0	3 5
13	33.0	10 0	11.0	7.5	13.0	8.5	67.0	10.0
14	31.0	13.0	15.0	6 0	22 0	4.5	30.0	7.5
15	120.0	16.0	16.0	6 0	18.0	5.5	27.0	7.5
16	20.0	20.0	19.0	5.5	21.0	3 5	205 0	6 0
17	50 0	13.0	19.5	4.0	17.5	5 5	210.0	8 5
18	45.0	13 0[a]	19.5	5.0	12.5	5.0	207.0	6.0
19	22.0	6.0[a]	22 0	4.0	12.0	3.5	95 0	7.0
20	21.0	12.0[a]	15.0	4.5	13.5	4.0	22 0	8.0
21	20.0	11.0[a]	11.5	6.0	21.5	13 5	18.0	8 0
22	110.0	11.0	12.0	4 5	11.5	6 5	50.0	12 0
23	26 0	6.5	19.0	7.0	8 5	12.5	60.0	6 5
24	35.0	8.5	17.5	5.5	30 0	5 0	60 0	12.5
25	36.0	8.5	21.0	7.0	12 5	10.0	80 0	6.0
26	53.0	9.0	11.5	10.0	8.5	7.0	35 0	8 0
27	43.0	6 0	11.5	10.0	11.0	4.5	21.0	6 0
28	120.0	11.0	22.0	4.5	13.5	8.5	55 0	6.0
29	105 0	12.0	28.0	6.5	11.5	3.5	19.0	6 0
30	260.0	12 0	19.0	5.5	11.5	6.5	60.0	8.0
31	21.0	10.0	35.0	7.0	18.5	5.5	17 5	7.5
32	40.0	6.5	17.0	6.0	10.0	6 0	18 0	8.0
33	38.0	7.0	18.0	6 0	9 0	3.5	18.0	8 5
34	21.0	9.0	13.0	5.0	22.0	8 0	22 0	7.5
35	35.0	8.0	13.0	5.5	12 0	14 0	12 5	10 0
36	37.0	5.0	22.0	8 5	9 0	4 0	18.0	6.0
37	20.0	6.5	20.0	7.0	11.5	7.5	12.5	5.0
38	21.0	7.5	15.0	11.5	10 0	10 0	12.0	4 5
39	18.5	6 0	21 5	6.5	8 0	10.0	17 5	12.0
40	18.0	11.0	42.5	12.5	10 0	5 0	23 0	6.5
41	22.0	10.0	12.0	5.5	9.0	10 0	22 0	8.5
42	20.0	8.5	10.0	7.0	8.5	10.0	45 0	5.0
43	12.0	8.5	13.0	3.5	8.5	3.5	14 0	7.0
44	17.0	6.0	13.5	5.5	11.5	5 0	13 5	5 0
45	7.0	6.5	12.5	4.0	8 0	6.5	11 5	6.5
46	13.0	6.0	22.0	8 0	11.0	12.0	8 5	5.0
47	25.0	10.0	16.5	6 0	9.0	7.0	17.5	7.5
48	11.0	5.5	17.5	4.5	17.0	6.5	17.5	5.5
49	16.0	5 5	13.0	4.0	7.5	10.0	15 0	7.5
50	18 0	7.5	8.5	4 0	8 5	9.5		

First test, trials 18–21, practise series 22–170, second test 171–199.

[a] First test. [b] Second test.

recognized to be the same as the initial position, but was thought to be something altogether new. The subject, consequently, failed to make use of the motor habits developed in the practise series. The times for the three trials of the first test were: 17.4 seconds, 10.6 seconds, 20 seconds; the times for the first three trials of the second test were: 32.4, 15, 10.4 seconds, the averages being respectively 16 and 19. The average for the entire last ten constituting the second test series was 15.2 seconds.

(4) The Chinese Ring puzzle is admirably adapted for use in transfer experiments in that the number of rings can be changed at will, and because the manipulation varies with each change, but in such a way that a single formula might be developed from the solution of any given case which would hold for all possible cases. Five arrangements of the puzzle were employed—(1) four rings, (2) five rings, (3) six rings, (4) seven rings, (5) ten rings. Each arrangement involved all the movements of all the forms preceding its own and some in addition. The number of movements necessary increased very greatly with each additional ring.

The tables show the records for eight subjects for the four-ring arrangement. Fifty trials each were taken with the puzzle in this form. Six subjects completed series with the five-ring form. These were carried far enough to get the method of manipulation well established for this form. Of the two subjects who do not appear in the table for the five-ring form one left the university and the other failed to solve. The subjects for the six-ring type are the same as for the five-ring type with the addition of *Wh.* He began with the six-ring form. Records for the seven-ring form were taken with three subjects and for the ten-ring form with four subjects.

The record of *Rd* is unique for the completeness of the transfer from one form to the others This may have been due in part to previous experience with another form of the Chinese puzzle. She had seen this other form fifteen years before. She had seen others work it and vaguely remembered the rule. She had not been interested in it, and was quite positive that she had never worked it herself. Nevertheless, the manipulation seemed familiar. If she had not worked it previously her present performance was certainly remarkable, for she not only did not make mistakes as to principle, but she reacted in large units directly whereas it was necessary for the other subjects to think out the detailed steps separately. In trial 1, four-ring form, *Rd* stated the rule vaguely; in trial 2 she described the process of solution explicitly, and in trials 5 and 7 worked out and described some short cuts. These short cuts were adopted at once and were maintained. *Rd* thus initiated the right habits of

TABLE XIV

CHINESE RINGS. FOUR RING FORM

	Eg	*Ob*	*Mc*	*St*	*Rd*	*Ta*	*Tr*	*Ba*
1	2,525.0	14,553.0	501.0	3,035.0	115.0	977.0	7,576.0	420.0
2	2,608.0	252.0	508 0	512.0	34.0	1,322.0	315.0	471.4
3	766.0	103.6	89.2	163 4	59.6	1,638.0	344.0	455.0
4	311.0	341.0	282.0	73.6	21.4	79.6	525.0	1,519.0
5	2,382.0	334.0	146.6	217.0	15.2	275.0	236.4	154.0
6	232.0	805.0	6,302.0	25.8	30.7	95.4	154 0	371.0
7	45.0	532.0	127.6	37.6	15.8	187.4	2,388.0	320.0
8	61.0	96.0	181.0	31.2	12.8	39.0	244 0	67.4
9	74.0	58.0	50.0	25.4	11.2	73.4	2,738.0	97.4
10	62.0	205.0	34 0	36.4	10.0	41.6	365.4	87.0
11	23.4	54.4	24 0	42.0	20.4	37.4	408.8	115.0
12	29.0	211.0	28.0	39.2	11.6	88.6	710.0	344 6
13	26.0	125 0	40 6	36 6	11.6	34.5	162.0	81.6
14	26.4	88.0	30.4	26.8	13.0	35.0	89.0	86 0
15	20.0	44.6	20.8	27.0	10.0	25 0	64.0	45 6
16	82.6[a]	108.0	48.8	31.6	12.3	22.0	41.6	55.0
17	50.0	245.0	28.4	19.8	11.9	29.6	96 4	60 8
18	29.0	80.0	24.0	30.0	12.6	80.4	56.6	169.4
19	25.2	111 0	34.4	25.4	15 3	19 6	33 0	34.0
20	26.6	129.0	24.0	24.0	10.3	18.0	25 0	135.6
21	20.0	65.0	22.6	22 0	11.3	17.0	39.7	142.6
22	27.0	131 0	23.0	19.6	13.4	28.2	27.5	32.6
23	20.8	138.0	21.0	80.0	11.8	20.4	29.8	25 0
24	19.0	72.6	22.0	20.8	15.3	32.0	19.6	23.0
25	17.0	32 8	16.6	29.4	12.4	22 2	19 2	34 6
26	28.0	35.0	14.6	62.6[b]	11.7	17.2	37.0	23.8
27	16.4	36.0	16 4	61.4	9.5	15.6	17.4	28.6
28	18.2	26.4	14.2	28.6	11.2	11.2	17.6	22.0
29	20.4	15.0	15.0	32.0	9.0	15 0	20.1	19 6
30	32.6	18.8	14.0	23.4	13.0	10.4	19.5	23.4
31	15.5	23.8	24 0	19.4	7.6	12 2	34.8	22.0
32	22.4	72.0	17.2	27.8	8 3	14.2	16.0	20.4
33	21.6	18.4	43.2	27.8	10 2	16 8	31.0	21 4
34	25.4	21.4	17.6	19.6	13 7	25.0	13.2	23.4
35	18.8	12.4	14 0	17.8	10 0	12.6	16 6	29.4
36	17.4	23.4	24.4	14.0	13 8	13.7	16.8	70 4
37	15.6	16.6	25 8	19 2	11.2	11.0	16 6	38.0
38	19.4	15.0	14.0	23 0	10.1	14.9	36.0	55 6
39	18.0	16.4	18 6	18 2	7.9	12.0	14.8	41.2
40	18.4	22.4	16 8	18.0	11.9	10.5	17.9	39 0
41	27.8	23.0	22 2	18.2	17.0	13.2	18.4	55.4
42	17.4	17.4	13 4	21.2	12 9	11.2	16 8	39 0
43	21.4	23.4	14.6	39.4	10.6	11.2	16.8	39.0
44	21.2	19.4	20.6	25 0	9.3	14.5	19.9	32 6
45	20.6	21.6	12 6	19.4	8 6	11.2	19 6	33.0
46	17.6	31.2	11.2	16.0	9 0	11.2	18.3	100 0
47	18.2	18.6	17.6	13.6	9.4	14.6	16 9	18 8
48	14.2	31.0	13.0	13 8	11.7	11.2	13 3	24.6
49	20.0	16 0	19.8	12.2	9.2	9.7	20 0	23.6
50	16.2	4,500.0[a]	24.8	13.4	8.3	10.3	13.1	22.0

[a] Two days later. [b] One day later. [c] Failure.

TABLE XV

CHINESE RINGS. FIVE-RING FORM

	Bg	*St*	*Rd*	*Tu*	*Tr*	*Bs*
1	1,020.0	1,678.0	42.0	985.0	84.3	704.0
2	275.0	2,670.0	30.0	140.0	173.8	903.0
3	331.0	635.0	32.3	431.3	332.0	269.0
4	294.0	1,115.0	30.8	449.0	86.8	166.6
5	186.0	424.0	25.3	130.0	57.2	175.6
6	185.0	1,299.0	40.0	127.0	84.0	117.0
7	91.0	1,374.0	31.0	68.0	54.0	234.0
8	98.0	580.0	23.0	64.0	51.6	294.0
9	186.0	211.0	23.5	57.0	55.0	97.8
10	107.0	1,196.0	29.4	41.0	67.9	164.0
11	109.0	493.0		42.6	61.8	57.0
12	76.6	65.0		50.6	68.0	73.0
13	95.0	245.0		38.0	48.3	65.0
14	73.0	133.0		80.0	42.2	71.0
15	49.4	495.0		43.3	45.7	49.6
16	60.0	167.0		90.0*		50.4
17	49.4	231.0		51.8		54.0
18	38.2	355.0		69.5		43.2
19	54.2	77.4		58.7		82.0
20	43.0	644.0		33.3		41.6
21	56.0	207.0		52.0		50.0
22		99.0		33.0		79.6
23		211.0		41.3		46.4
24		97.0		37.3		56.0
25		92.6		31.0		52.6
26		39.8		38.8		
27		186.0		34.2		
28		535.0		32.0		
29		310.0		29.0		
30		175.0		29.8		
31		94 0		37.0		
32		113.6		39.2		
33		65.0		32.2		
34		56.0		35.0		
35		46.0		37.0		
36		65.0				
37		50.0				
38		116 0				
39		53.0				
40		43.7				
41		142.0				
42		154.0				
43		50.0				
44		60.0				
45		60.0				
46		65.0				
47		62.6				
48		84.0				
49		61.8				
50		73.7				

* 24 hours later.

TABLE XVI

CHINESE RINGS. SIX RING FORM

	Bg	*St*	*Rd*	*Tu*	*Tr*	*Bs*	*Wh*
1	249.0	270.0	86.3	470.0	182.0	1,595.0	10,830.0
2	676.0	58.3	71.5	168.0	210.0		1,080.0
3	980.0	63.2	54.7	71.3	141.6		390.0
4	296.0	72.0		99.5	103.2		237.0
5	393.0	49.0		76.4	95.6		175.0
6	380.0	53.8		72.2	83.8		137.0
7	150.0	53.2		66.9	118.6		110 0
8	114.0	305.0		60.5	98.0		85.0
9	130.0	55.0		57.6	69.0		81.0
10		55.4		56.6	56.8		134.0
11		52.0					100.0
12		53.0					
13		47.7					
14		47.3					
15		377.6					
16		48.0					
17		47.8					
18		50.0					
19		63.0					
20		57.0					

SEVEN RING FORM

	Rd	*Tu*	*Tr*
1	112.9	1,290.4	332.4
2		235.0	
3		206.6	
4		174.4	
5		156 7	
6		170.0	

TEN-RING FORM

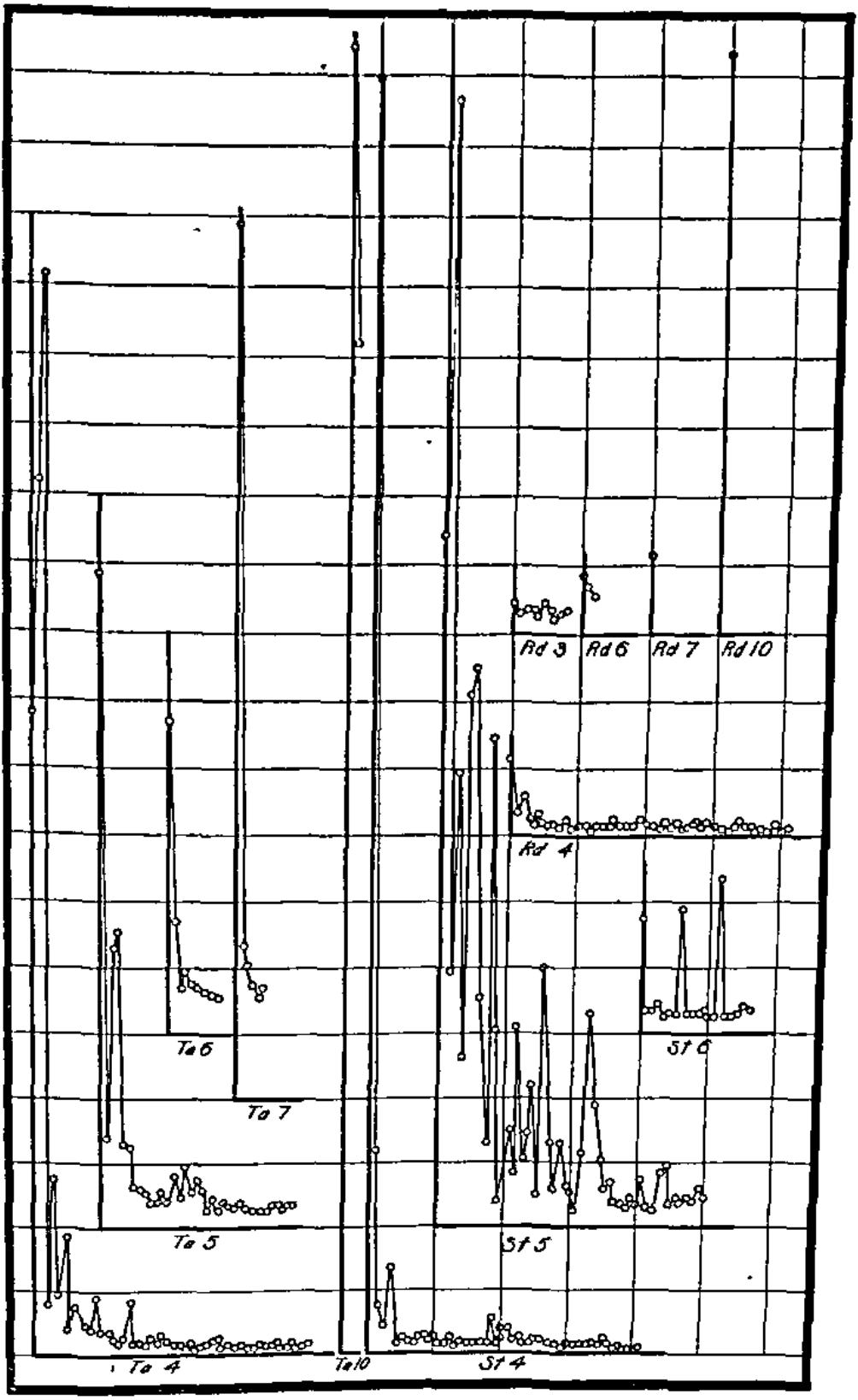
	Rd	*Tu*	*Tr*	*Wh*
1	824.6	1,935.0	2,142 0	1,260.0
2		1,521.0		

manipulation from the start and did not have to contend against the reappearance of erroneous methods as did the other subjects.

The records for *Co* and *St* form a striking contrast to those of *Rd*. Both of these boys moved rapidly and they were quite variable in their movements. This was especially true of *St*. Where other boys would stick, he would find a way out simply by means of his greater variability, rapidity and pertinacity. *Co* finally learned the particular combination required for the four-ring form, but he did not develop a formula for it or even see the necessity of the order of movements which he finally settled upon. At the twenty-fifth trial

he began the control of one of the part processes which had previously been uncontrolled, and his curve drops abruptly here to a lower level. After having solved the puzzle twenty-four times more he, however, failed to solve it in the fiftieth trial. A chance move put the puzzle into a novel position, and he was unable to get it back, although he spent 4,500 seconds in the attempt. The solution of this novel position was an essential step in the solution of the five-ring form of the same puzzle, and he consequently failed in that.

St made an analysis in trial 6 which enabled him to avoid *Co's* difficulty, and his curve drops abruptly to a permanently low level. His records at the close of the fifty trials with the four-ring form are the third from the best. With the change to the five-ring form, however, his records are by far the worst. The curve remains high and fluctuating until the forty-third trial, and even then his times are much longer than those of any other subject, although *St* had had the benefit of from fifteen to forty more trials with this form than the other subjects. That this result was not due to lack of variability or concrete analysis, nor to lack of motor facility, is shown by his records in the four-ring form. The reason for this failure of transfer is that *St* did not develop a general formula on the basis of the special case given in the four-ring form. The initial movements in solving the five-ring arrangement are precisely similar to those in solving the three-ring form but they are different from the first movements with the four-ring form. Now the three-ring form comes in as a part process in solving the four-ring form, and so *St* had had the opportunity to discriminate and to generalize on the basis of the discrimination. He learned to react differently to the four-ring and the three-ring combinations, and this fact enters into the explanation of what success he did obtain with the five-ring form. He reacted to the five-ring form, however, precisely as if it were the four-ring form. This only made the solution more difficult because all the steps thus initiated had to be done over again, and this method of attack led into situations from which it was very difficult to extricate himself. *St's* method finally became stereotyped, but it included the following serious error. He would take off the first four rings as if it were the four-ring form, and then he would put them all back on again. The puzzle would now be exactly as it was to start with. He would then go ahead and solve correctly. There was transfer here, but with a vengeance. The motor habits were transferred entire, uncontrolled by any analysis of relations. There was, however, positive as well as negative transfer, since he succeeded in solving after having retraced the false steps, and the three-ring habit evidently came in on the second attempt.



CHINESE RINGS PUZZLES, NOS. 26 AND 30

4- and 5 ring forms obtained by modification of No. 30; 7-ring form obtained by modification of No. 26. *To* 4, 5, 6, 7, 10—scale: smallest division = 10″; *Rd* 4, 5, 6, 7, 10—scale: smallest division = 10″: *St* 4, 5, 6—scale: smallest division = 16″.

This result with *St* illustrates the point made in an earlier chapter, that a single practise curve is not sufficient as a mental test but that it should be supplemented with other curves on variants of the original test, and that by decreasing the points of similarity between the original problem and its variant the difference in capacity between subjects can be more rigidly tested.

It might seem surprising, at first, that *St*'s records with the six-ring form should be lower than with the five-ring, despite the fact that the addition of one ring approximately doubles the total time of manipulation. It is also noteworthy that in the six-ring form his low times are lower than those of any other subject, including *Rd*. *Rd*, to be sure, made only three trials, but *St*'s time for trial 5 is considerably lower than *Rd*'s for trial 3. This again shows that *St* was not lacking in speed or accuracy of movement, but excelled in them. The reason for his success with the six-ring form is that it is solved by using the same initial movements as the four-ring form. *St* carried over his four-ring habits again, but this time they happened to be appropriate. The high times in trials 8 and 15 show the lack of the fundamental principles. In each of these trials he made the same serious error four times.

The high times for trials 1–11, *Bg*, with the five-ring form were due also to carrying over the method of solution from the four-ring form unchanged. The high times of the six-ring form were due to the carrying over of the method of starting finally adopted for the five-ring form. *Bg* had become explicitly conscious of the different ways of starting necessary for the four-ring and five-ring forms, but he did not generalize so as to include the next change.

Ta did not work out the generalization as to method of beginning until trial 5 of the seven-ring form, although he had suspected it before. In each change, previous to that from the seven-ring to the ten-ring form, there had been negative transfer in beginning, *i. e.*, he had used the method appropriate to the form just preceding.

These three cases form an ascending scale in that *St* did not discriminate the beginning of the five-ring form from the four-, that *Bg* made this distinction but did not generalize it so as to include the six-ring and other forms, and that *Ta* did explicitly generalize so as to include all possible forms, although he did this so late that there was but one application.

Tz seems to have gotten the generalization earlier, in the four-ring form, but not quite explicitly and the effects of his idea were masked by the revival of inappropriate habits which had become established early in the four-ring series.

Wh began with the six-ring form instead of the four-ring form of

the other subjects. He worked out the general formula of solution in trial 1 and developed the rule for the initial movement as dependent on the number of rings and as applicable to any possible number of them in his second trial. As a result of working out this formula *Wh's* times for this form after only two trials are lower than those of another subject who had solved the puzzle in the four- and five-ring forms over seventy times but who had not developed a general formula for starting.

Some details will now be given from *Wh's* notes. *Wh's* analysis in trial 1 has been given above.*

Trial 3: "Worked strictly according to plan outlined."

Trial 4: "Same as above. . . . When first ring is on, it is only necessary to get it above the bar, not around it, before slipping the first two off." (This is a valuable short cut.)

Trial 5: "I can see that time will be saved by remembering by rote whether to start by dropping 1 or 2. So far I have always figured it out. The fourth has to come off to allow the sixth to come off, therefore the second has to come off." Already there has been some short-circuiting here, because the getting off of the fourth ring is really conceived as a unit.

Trial 6: "Same as before. Quicker start by rote. Hesitation *after* the sixth was off and figuring out of return."

Trial 7: "Same method: Rote in getting off sixth and in remembering always to start, in putting on, with first and second, then third, etc. Less hesitation about method of putting rings on—up through and over instead of over and down through as in dropping them."

Trial 8: "More effort at speed. Time saved in the return by beginning promptly at the left side and passing the dropped ring up through and over end. Still hesitations at transition points."

Trial 9: "Transitions more automatic. More feeling of knowing where I am."

After ten more trials on a subsequent day with taking the puzzle apart and twenty-two trials in putting it together *Wh* was given a five-ring form which also differed considerably in appearance from the six-ring type he had been using. He solved this without error the first time. To quote—trial 1: "A good deal like another I've tried, why not the same thing? . . . I tried the movements without much detailed examination and found that the same things could be done, though the friction was greater. There were but five rings instead of six, and therefore the beginning had to be made by dropping one instead of two as in the previous puzzle."

* See p. 27.

The tendency of habits to transfer inappropriately despite the understanding of the general principle is illustrated by a quotation from trial 3. "The old habit of dropping two as the first move (correct for six rings) tends to persist. Both the last time and this I started in this way, though I recovered myself in a few seconds."

Wh was later given the ten-ring form of the puzzle to solve. The solution of the ten-ring form includes the actual solution of all the lesser forms, nine, eight, seven, six, five, four, three, two as component parts of itself. *Wh* solved this the first time without error and in very quick time. *Rd* was the only one to solve it in less time and she had developed or partly revived and developed the same *formulæ* during her first trials with the puzzle and she had also carried through a long practise series. In solving the ten-ring form both of these subjects reacted to large units, and avoided confusions into which the other subjects, whose attention was more on details, often fell. The other subjects would forget in which direction they were going at times and so retrace their steps. One subject thus retraced a long subprocess five times in a single trial. Since the taking-off process for a given number of rings, say eight, involved putting on the first six rings, and since the putting on and taking off alternated, it was easy to become confused as to the general direction if the subject's attention were on details.

The experiments with the Chinese puzzle have some points of similarity with Judd's experiment[10] of throwing the darts at an object under water. In this case, however, the fact that there was a general formula that could be applied to all the cases was not even suggested to the subjects.

(5) The Mounted Wire Loop and Chain puzzle is a variation on the Chinese ring. The method of solution is precisely the same, but the superficial appearance is very different. The table for this puzzle shows that there were decided transfer effects from the Chinese puzzle. *Be* is the only subject who solved this puzzle who had not previously solved the Chinese ring. He had not attempted the latter, and had made very good records in the puzzles he tried. His records might, then, be taken as a standard from which to reckon the transfer gained by other subjects. Of these, the series of *Rr* shows the least transfer. He had done the Chinese puzzle but a few times and that was seven months previous to the time concerned. He had worked out the general formula of the Chinese ring in the first trial but he had not developed the important corollary as to the initial movement at that previous time. *Rr* used parts of the Chinese ring

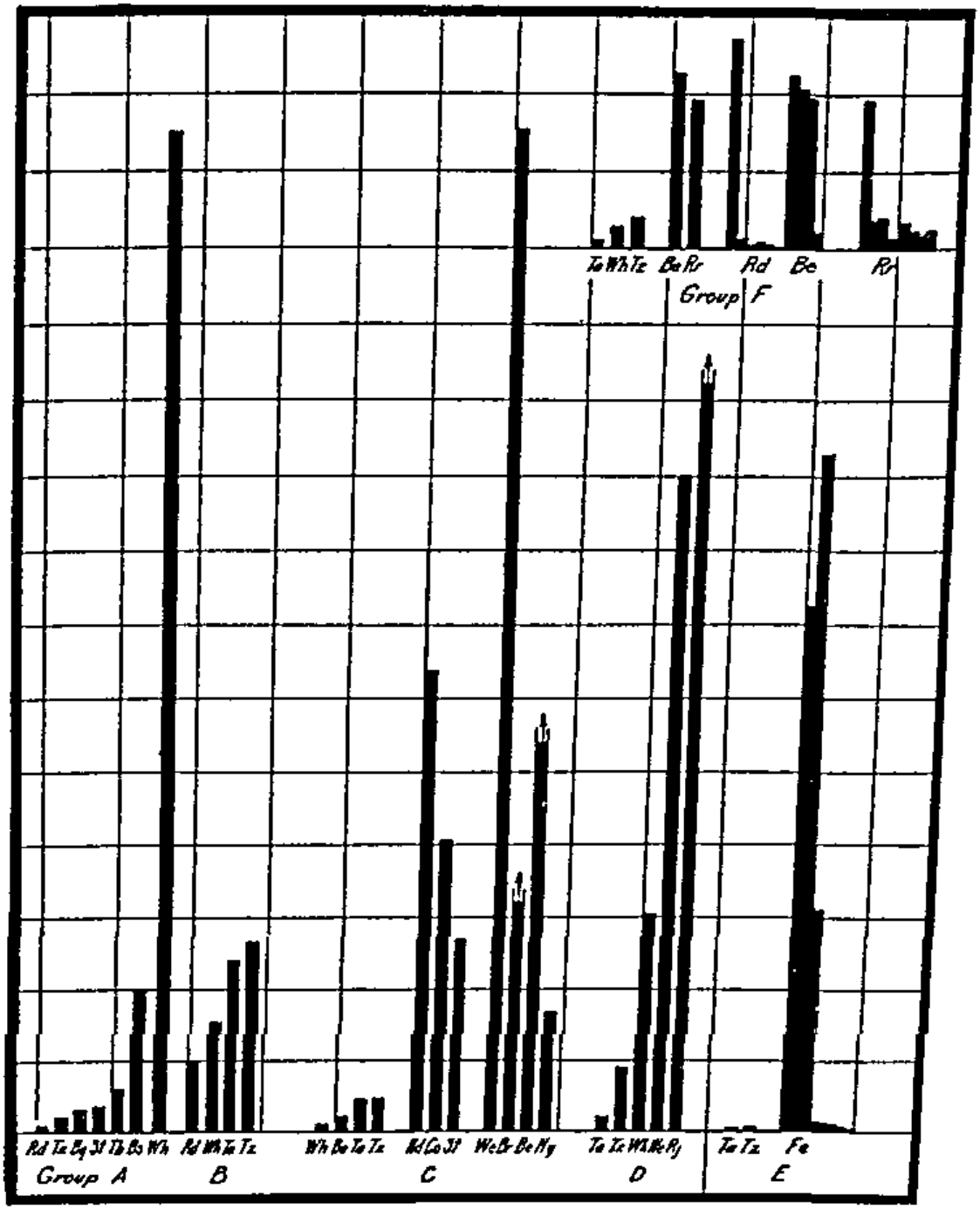
[10] *Educational Review*, Vol. XXXVI., pp. 38–42.

TABLE XVII

Mounted Wire Loop and Chain

	Off *Er*	On	Off *Wa*	On	*Rd*	*Ta*	*Ts*	*Be*
1	1,560.0	1,660.0	220.0	93.0	2,162.0	94.3	321.8	1,500.0
2	290 0	294.0	62 0	58.0	98.0	52.5	51.6	1,653.0
3	300.0	283.0	58.0	54.0	37.6	47.6	39.3	1,566.0
4	70.0	106.0	60.0	38 0	51.4	36.0	41.9	186.0
5	264.0	188.0	37.0	47.0	38.0	36.0	32.0	
6	202.9	97.0	34.0	48.0				
7	175.0	65.0	54.0	40 0				
8	195.0	89.0	40 0	32.0				
9		93.0	32.0	98.0				
10	110.0	52.0	42.0	37.0				
11	114.0	55.0						
12	121.0	61.0						
13	56 0	51.0						
14	72.0	45.0						
15	205.0	51.0						
16	53.0	62.0						
17	165.0	55.0						
18	63.0	47.0						
19	114 0	54.0						
20	58.0	44 0						
21	121.0	46.0						
22	57.0	41.0						
23	120.0	28.0						
24	54.0	41.0						
25	31.0	29.0						
26	140.0	28.0						
27	43.0	76.0						
28	38.0	27.0						
29	65 0	30.0						
30	34.0	56 0						
31	57.0	95.0						
32	78 0	29.0						
33	43.0	35.0						
34	33.0	24.0						
35	37.0	29.0						
36	32.0	120.0						
37	31.0	38.0						
38	32.0	27.0						
39	30.0	28.0						
40	35 0	26.0						
41	36 0	26.0						
42	26 0	26.0						
43	24.0	20.0						
44	30 0	30.0						
45	27.0	21.0						
46	26.0	22 0						
47	33.0	22.0						
48	26.0	21.0						
49	25.0	22.0						
50	24.0	21.0						

PLATE VII



GROUP A. CHINESE RING (6-RING)—PUZZLE No. 30

Previous practise series on closely related 4- and 5-ring forms by all subjects except *Wh*. Transfer from 4- and 5-ring form to 6-ring shown by comparison of *Rd* or *Tz* with *Wh*.

GROUP B. CHINESE RING (10 RING)—PUZZLE No. 26

Time of optimum manipulation of 10-ring form is ten times that of 6-ring; *Wh*'s times for the 10 ring is one ninth that of his time for the 6-ring. The transfer here is connected with a thorough analysis and a verbal statement of the rule of procedure.

GROUP C. HINGED RECTANGLE—PUZZLE No. 12

This is a complex of several elemental devices, each being found isolated in simpler puzzles. All of these simpler puzzles were known by *Wh*, who at once perceived and utilized the similarities involved. *Bg*, *Ta* and *Tz* show transfer of a part of these elements; one was not known to them. *We*, *Br*, *Be*, *Hy*, and *Rd*, *Co*, *St* either lacked the original experiences or failed to utilize them.

GROUP D. BICYCLE—PUZZLE No. 2

Ta and *Tz* show immediate and almost total transfer from puzzle 4; *Rj*, no transfer-failure; *Wh* and *We*, utilization of scientific method, without much transfer from related puzzles.

GROUP E. HOOK AND EYE—PUZZLE No. 5

Ta and *Tz* showed marked transfer from puzzle No. 4. Contrast results with *Fe*'s: *Fe* recalled puzzle 4, but failed in transfer because of lack of analysis.

GROUP F. MOUNTED WIRE LOOP—PUZZLE No. 35

See text, Transfer (5).

All records on Plate VII. are for trial 1 only except *E–Fe*, and *F–Rd–Be–Rr*.

Scale for groups A, B, C and F is 80 seconds to smallest division, and for groups D and E is 20 seconds to the smallest division.

solution as they occurred to him, but he did not revive the whole process nor make the complete identification. There was evidently some little transfer, however, if the comparison with *Be's* record may be taken at face value.

Wh had solved the ten-ring form of the Chinese puzzle on the day previous to his solution of the puzzle under consideration. He made a complete identification of the two puzzles and carried over his methods and habits apparently without loss.

Rd had carried the manipulation of the Chinese ring puzzle to the highest perfection reached by any of the subjects, yet her initial time for the Mounted Wire Loop is longer than for any other subject. This was due to the fact that she had failed to make an explicit discrimination as to one point of detail in the earlier series. This was probably due to the fact that no difficulty chanced to arise at that point and that correct habits of manipulation were built up although they had not been based upon a careful analysis of correct and incorrect forms. *Tz* and *Ta* had both encountered the difficulty in the Chinese Ring series and they avoided it with the Loop.

After *Ta* had spent 30 seconds of trial 1 in examination he moved the puzzle to see if a novel position might not result which would suggest something. (This was a general method of his.) The similarity to the Chinese rings immediately flashed across his mind, and he called up an image of that puzzle and the rule for solving it. This rule he applied directly to the Mounted Wire Loop. *Tz* also made the identification in trial 1. The low times for the second trials of *Wh, Rd, Ta* and *Tz*, show, if compared with that of *Be*, the transfer effect from the Chinese ring.

In the case of the curves for *Wh* and *Rr* it will be noticed that times are given for taking the puzzle apart and also for putting it together, the subjects acting also as operators. Comparison of the off and on series for *Rr* will show that there was no complete transfer from one series to the other. The initial time for the on series is longer than that for the off, and the break in the on curve comes much more quickly and sharply than in the off. This drop was due to a detail analysis suggested by the Chinese rings and also from the off series. The idea transferred from the off series was that of the successive movements forming a reversal. It is interesting that this idea should seem to have been more effective in the on series than in the off. The transfer between the off and on series was here clearly due to an idea.

2. General Discussion and Summary

The following summary includes a résumé of results presented in other chapters as well as this one.

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2. General Discussion and Summary

The following summary includes a résumé of results presented in other chapters as well as this one.

To the writer, the problem consciousness considered in itself and as to conditions of efficiency seems to have many characteristics in common irrespective of the degree of relatedness of the material concerned. Since in the writer's view the course of efficiency in the practise curve is largely a matter of securing the appropriate variations and of their conscious control, the problem consciousness would, from the standpoint of efficiency, be almost universal in scope and its general features or factors would serve as means for transfer of an extensive sort. The distinction was made above between direct or necessary transfer and conditional transfer, the latter involving an act of analysis. The statements above in reference to the wide possibility of transfer presuppose in the main such acts of analysis.

The following classification of transfer factors is based directly on the puzzle experiments. Some of the special factors are naturally specifically related to the puzzle series while the general factors seem to be of wide applicability. The conditions of transfer of the special factors are believed to be general although the material itself may have been specific.

A. *General Factors*

(*a*) *The Ideal of Efficiency.*—This involves the active search for methods of control, and would properly embrace all the succeeding factors.

(*b*) *Level of Attention.*—High level attention was a precondition of success. Transfer of this factor seemed to be both direct, a result of change of attitude, and indirect, a result of the idea of its value and conscious attempt to realize it, as by effort of will, control of physical condition, search for stimulus.

(*c*) *Attitudes.*—The change from the self-conscious to the problem-attitude occurred sometimes automatically, and sometimes deliberately by means of an ideal. The most powerful stimulus to change of attitude and so of its transfer was personal success. It did not matter much whether it was accidental or planned.

(*d*) *Methods of Attack.*—(1) Conscious control of assumptions. The value of explicit consciousness of the assumptions made concerning a problem and of openness of mind and active search for other assumptions than the chance first one was recognized and generalized as a point of method common to the different situations encountered.

(2) The dilemma seemed to prove itself of considerable value as a stimulus to discovery of novel points of view both as to the nature of the problem and as to minor features. The dilemma was consciously generalized as a method of attack.

(3) Active search for distinctions and for their appropriate classification took place independently of the use of the dilemma, and constituted a highly general form of method.

(4) The search for new points of view at times took the form of random manipulation, now in the hope of gaining success by an accidental variation, and, again, in anticipation of a happy suggestion from some chance position. These methods of attack were consciously generalized and applied.

(5) The careful testing of hypotheses as opposed to mere repetition was a consciously adopted general point of method.

(6) The ideal of the value of generalization, and of statement in a formula, was noted as a case of conscious transfer.

B. *Special Factors*

(*a*) *Related Ideas.*—(1) Geometrical concepts played an almost negligible part in the work of solution. This was especially true of tridimensional puzzles. What was needed was ability to construct transformations in three dimensions and the static training of geometry seemed at times even to interfere with the dynamic problem. The concept of symmetry was of some value, but in the main the transfer value of mathematics in so far as it appeared seemed to be largely in the form of general methods, as that of considering the problem solved and working the solution in reverse order. The failure of mathematical training to develop the capacity or capacities for dynamic construction was rather striking.

(2) Ideas of common objects in connection with which movement was a familiar feature, as rubber bands, were employed with some success.

(3) The greatest transfer in the way of related ideas was that from similar puzzles. Transfer of this sort also gave the most immediate solutions. The mere presence of a vivid image of a closely related puzzle was not sufficient, however, of itself. A distinct act of analysis was necessary in addition. The analysis was at times apparently due to previous experience and yet took place as an immediately perceptual act without the revival of distinct imagery.

(*b*) *Motor Habits.*—(1) The mere presence, in the case of change of conditions, of motor habits appropriate to the new conditions did not necessitate positive transfer. It could coexist with negative transfer.

(2) The degree of positive transfer varied directly with the precision of analysis of the similarity of the new case to the old. The similarity suggestion needed, as was the case with memory sug-

gestions, to be treated as an hypothesis to be held tentatively and tested rather than to be accepted at once at face value and then persisted in unquestioningly

(3) In some cases a generalized formula developed in connection with the first case was essential to effective transfer of motor habits to later modifications of the first case

(4) Transfer was more effective in those cases where the formula or general rule was developed in the first few trials, and where the formation of perceptual motor habits had been controlled and interpenetrated by it from the start, than when the generalization had been arrived at after those habits had been set up

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